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TECHNICAL ASPECTS OF BIOLOGICAL DEFENSE

DEPARTMENTS OF THE ARMY, AND THE AIR FORCE

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CHAPTER 1

INTRODUCTION

1. Purpose and Scope

a. This manual provides information on the technical aspects of biological defense against enemy biological attacks as applicable to a biological weapon system, to include infection and immunity; methods of dissemination; detection and defense; and potential biological antipersonnel, antianimal, antiplant, and antimateriel agents. This manual is intended primarily for use by Army chemical staff and Air Force munitions staff personnel and by CBR-trained defense personnel. However, the manual also may be of value to other personnel of ground and air units who may need an understanding of the technical aspects of defensive measures against enemy biological attacks.

b. The material presented in this manual is applicable to both nuclear and nonnuclear warfare.

c. Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be prepared using DA Form 2028 (Recommended Changes to Publications) and forwarded direct to Commandant, U.S. Army Chemical Center and School, Fort McClellan, Ala. 36201.

2. Definitions of Biological Agents, Weapon Systems, and Operations

a. Biological agents are living microorganisms which cause disease in man, animals, or plants or cause the deterioration of materiel. Microorganisms, as used in this manual, will refer to living microorganisms unless otherwise specified. For the purposes of this manual, virus particles are considered to be living agents.

b. Biological weapon systems consist of an agent, a munition, and a delivery system.

c. Biological operations are the intentional employment of biological agents by biological weapon systems to produce casualties or damage to humans, animals, or plants or to cause the deterioration of materiel.

d. Additional definitions of terms used throughout the manual are included in the glossary.

3. Objective of Biological Operations

The ultimate objective of biological operations is to directly or indirectly reduce a target population's ability to wage war. This objective might be achieved directly by attacking man himself. It also might be achieved indirectly by attacking man's crops, domestic animals, or supplies, thereby limiting his means of support.

4. Historical Background

a. On every battlefield the soldier has had to fight disease as well as the enemy. Disease has proven to be a formidable antagonist, determining the outcome of many battles. Prior to the development of modern medicine, disease killed more soldiers than did actual combat. This was due to overcrowding, poor camp hygiene, inadequate medical support, and the physical stresses of combat. World War II was the first war in the history of the U.S. Army where deaths from combat exceeded those from disease. But death from disease is not the only problem. The fighting strength of the U.S. Army in World War II was significantly weakened by lost man-days due to sickness. The number of lost man-days due to naturally occurring disease was equivalent to 18 U.S. Army infantry divisions operating for a 3-year period, 1942 to 1945 (fig. 1).

b. The military potential of disease has not been overlooked. If naturally occurring disease can have a major military impact, how much greater could that effect be if disease-producing microorganisms were employed intentionally? Biological operations are not new. The contamination of water sources by corpses is an ancient

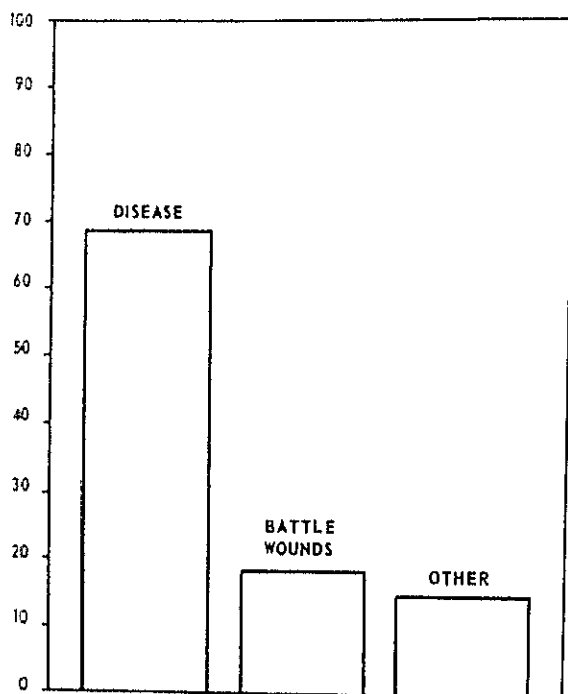


Figure 1. Percent man-days lost during World War II due to disease and battle wounds.

technique. The popular notion was that foul odors and decaying material could cause disease. In the Middle Ages this misconception led to the hurling of corpses and excreta into besieged cities by means of an immense machine called a trebuchet. A more sophisticated approach was used by the British against the Indians at Fort Pitt, Pennsylvania, in 1763. The British commander infected the local Indian tribe with smallpox by giving them blankets taken from smallpox patients. The Indians had a low biological resistance to the disease and many died.

c. In the 20th Century there have been numerous allegations about the use of biological agents. There is one case which is supported by substantive evidence. During World War I, Germany used the causative agent glanders to infect French and Romanian cavalry horses. Biological agent research was active in Germany and Japan during the 1930's. The threat that this effort posed to the Free World was evaluated in the United States by the National Academy of Sciences. This study determined that "the value of biological warfare will be a debatable question until it has been clearly proven or disproven by experiences. The wide assumption is that any method which ap-

pears to offer advantages to a nation at war will be vigorously employed by that nation. There is but one logical course to pursue, namely, to study the possibilities of such warfare from every angle, make every preparation for reducing its effectiveness, and thereby reduce the likelihood of its use." This report led to the development of the U.S. Army biological defense research program in 1942.

5. General Characteristics of Biological Agents

Biological weapon systems are technically feasible. They possess a mass casualty potential which cannot be safely ignored. It is imperative to be able to defend against biological attack. The first step in preparing a sound defense is to understand the nature of the threat. This involves sweeping away some of the misconceptions associated with biological agents. These agents are not the ultimate weapons referred to by science fiction writers. The general characteristics of biological agents place their threat in perspective.

a. *Low Agent Requirement.* Biological weapon systems are unique in that the agents involved are alive. Only a small number of microorganisms are needed to establish infection. The agents reproduce in the host to bring about disease. A natural regional outbreak of a disease which affects many individuals and which can spread rapidly is called an epidemic (epizootic in animals and epiphytotic in plants). In such a situation there is an unusual increase in the number of cases of a disease in a limited time among a limited population. In nature, the spread of disease occurs from direct contact between individuals, contact with or ingestion of excreta and contaminated food, exposure to dusts and mists of infective material (aerosols), and from transmission by animal or arthropod vectors. Following large-scale dissemination of a biological agent, an initial outbreak of disease of epidemic proportion might occur. This depends upon the contagiousness of the agent, the presence or absence of favorable environmental conditions, and the level of medical support. Epidemics among the human population can be controlled or minimized by sanitation, immunization, quarantine, and treatment. Rapidly spreading epidemics are not considered to be the likely result of a biological attack in a civilized country so long as controlling factors remain at a high level of efficiency. The potential for epizootics among animals or epiphytotics among plants is greater than for epidemics

among humans, hence smaller quantities of agent are needed to produce effective results.

b. Large-Area Coverage. Biological weapon systems have the potential to cover larger areas than other weapons. Extremely large numbers of infective doses of biological agents can be of small volume because the size of the organisms is microscopic. A single delivery vehicle can cover target areas up to thousands of square kilometers with a casualty-producing biological agent aerosol.

c. Dependence on Weather. There are four significant weather conditions which directly affect a biological agent aerosol. These are *sunlight* (ultraviolet radiation), *relative humidity*, *wind* (both speed and direction), and *air stability*. Ultraviolet radiation is lethal to most biological agents; therefore, most biological attacks may be expected at night. Each potential biological agent, once aerosolized, has an optimum relative humidity requirement for survival. Therefore, the degree of variance from the optimum influences the rate of decay of an aerosol. However, there are some potential biological agents which in the aerosol form are not significantly influenced by the relative humidity. The importance of wind effects varies with the type of weapon system used to disseminate the agent. If dissemination is by a weapon that releases the agent directly on target, then wind direction and speed have little effect on the target coverage; however, downwind effects from the target must be considered. If dissemination is by a weapon that releases the agent upwind of a target area, then the wind must carry it to the target area. Normally, the most effective wind speeds for effective target coverage with a biological agent aerosol involving downwind travel are from 8 to 18 knots.

d. Delayed Effect. Biological agents do not cause casualties immediately. Time is required for the agent to reproduce in the host. After the microorganisms have multiplied in sufficient quantity, they may overcome the body defenses and cause disease. There is a period of time from the time of entry of microorganisms into man to the time he is actually sick and becomes a casualty. This period of time-to-casualty (incubation period, para 17b) is typical for each agent and varies from a few days to a few weeks or months.

e. Pervasive. The particles of biological agent aerosols are so small and light that they are carried by wind currents into dug-in positions, fortifications, or other nonairtight shelters and structures. So-called hard targets for other weapon

systems would not be considered hard targets for biological weapon systems. It is possible that the dose received inside a nonairtight structure may exceed that received on the outside. This is true because the structure, once penetrated, affords protection for the agent; and it will probably persist for a much longer period of time.

f. Nondestructive. Since biological agents (other than antimateriel agents) affect only living things, equipment, facilities, and structures will be left intact after a biological attack has occurred. In addition, biological explosive munitions usually utilize very low order explosives for dissemination of the agent. Such explosions are not of sufficient force to produce any significant destruction. Spray weapon systems are completely nondestructive.

g. Difficult to Detect. Biological agents that are disseminated as aerosols are not detectable by any of the five physical senses (sight, smell, taste, touch, and hearing). When man comes in contact with such an aerosol, he inhales the organisms without suspecting he has been the target of an attack. Effects do not occur immediately, so the attack goes unnoticed. It is only with special instruments that the presence of biological agents can be detected. At present, the capabilities of such instruments are very restricted.

h. Decay of Agent. Since biological agents are living microorganisms, they are affected by environmental conditions during storage and shipment and when disseminated. Refrigeration is necessary during storage and shipment to reduce the rate of loss of viability and virulence of the agent. The rate at which most microorganisms die off is predictable and is referred to as the "decay rate."

i. Easy to Produce. Biological agents are the least expensive of the mass casualty weapons. An enemy nation with a modest biological research or production base; such as in the pharmaceutical or brewing industry, can produce biological agents.

j. Severity of Effects. Effects might be either lethal or nonlethal (incapacitating). Lethal or killing agents can produce death in susceptible individuals, but from a practical standpoint death occurs only in a certain percentage of those exposed. The nonlethal pathogenic agents usually do not kill but might produce infection or disease with militarily significant disability among sus-

ceptible exposed individuals. Food and industrial products can be rendered unsafe or unfit for use

by contamination or by the effects resulting from contamination with biological agents.

CHAPTER 2

TECHNICAL ASPECTS

Section I. GENERAL

6. Microbiology Applied to Biological Agents

The military application of microbiology concerns only those microorganisms which may be deliberately employed in weapon systems to cause disease or death to man, animals, or plants, or to cause deterioration of materiel. Biological agents consist of microorganisms such as bacteria, rickettsiae, viruses, and fungi. Although some protozoa are pathogenic microorganisms, they presently have little military significance for use in weapon systems. Characteristics and properties mentioned in this manual under the general term "microorganisms" will refer to bacteria, rickettsiae, viruses, and fungi unless otherwise indicated.

7. Explanation of Terms as They Pertain to This Manual

a. Viability. The viability of microorganisms varies with the species. Since biological agents are living organisms, most of them are significantly affected by environmental conditions. While most

vegetative microorganisms might be killed or attenuated by environmental factors, some agents can survive for prolonged periods if conditions are favorable or if natural reservoirs are established. In general, sporulating bacteria, such as *Bacillus anthracis* and *Clostridium botulinum*, and the fungal spores remain viable in the environment following dissemination for greater periods of time than nonsporulating microorganisms.

b. Virulence. Virulence is the relative severity of a disease that a pathogen is capable of producing. Virulence depends on a number of factors such as the particular strain, its passage through living hosts, and the presence or absence of powers of invasiveness and toxicity (para 18c).

c. Communicability. A communicable disease is one which is transmitted directly or indirectly from one host to another by contact, body excretions, coughing, or sneezing. Such diseases as diphtheria, typhoid fever, mumps, and measles are communicable; however, tetanus and botulism are not.

Section II. CHARACTERISTICS OF MICROORGANISMS

8. General

a. Description. Microorganisms are living organisms which usually are too small to be seen by the unaided eye. When observed with a microscope, each microorganism is found to be composed of a single cell or of a group of associated cells. Each cell, or group of associated cells, is capable of carrying on all the functions of life including growth and reproduction. A microorganism requires food in a soluble form so that the nutrients can pass through the cytoplasmic membrane which surrounds the cell. A microorganism assumes the temperature of its surroundings because it has no heat regulating system. Many microorganisms resemble plant life

and are regarded as members of the plant kingdom. Others, including the protozoa, have characteristics which cause them to be placed in the animal kingdom.

b. Types of Microorganisms. On the basis of structural and behavioral characteristics, microorganisms may be grouped, in order of decreasing size, as follows: fungi, protozoa, bacteria, rickettsiae, and viruses. Microorganisms are so small that the unit applied in their measurement is the micron, which is equivalent to 1/1,000 of a millimeter or 1/25,400 of an inch.

c. Pathogenicity. Of the hundreds of thousands of microorganisms which exist, only a few hundred are capable of producing disease in man,

plants, or animals. Those microorganisms which are capable of producing disease are called pathogens. Most microorganisms, however, are non-pathogenic and are in fact beneficial to animal and plant life. Some of the most powerful antibiotics, such as chloromycetin, penicillin, and streptomycin, have been obtained from the metabolic processes of certain microorganisms. Microorganisms are important in the preparation of dairy products, bread, and vinegar, and in fermentation processes. Soil fertility is largely dependent upon the activity of microorganisms in decomposing dead organic matter which releases elements needed for the growth of plants. Those organisms that live within a host from which they obtain food without benefit to the host are parasites. Many of the pathogens are parasites. Organisms which reproduce in dead rather than in living matter are called saprophytes. While most of these are harmless, some cause disease and others produce poisonous substances. Examples of some of the harmful saprophytes are the bacteria which cause tetanus and botulism. Bacteria that cause tetanus produce their toxins while growing in injured and devitalized tissue of the host. The botulism organism produces its toxin in certain foods. Ingestion of food containing botulinum toxin can cause highly fatal poisoning.

d. Distribution. Microorganisms are universally distributed in air, water, and soil. Soil microorganisms are found on surfaces where dirt and dust tend to accumulate, and every cubic foot of soil provides a natural home for billions of them. The skin, hair, nose, mouth, and digestive tract of man and animals harbor a variety of microorganisms in large numbers. In nature, the pathogenic or disease-producing microorganisms of man, animals, and plants, with few exceptions, do not survive long or grow well in the absence of a suitable host because favorable environmental conditions necessary for their survival are not present.

9. Growth

Numerous factors influence the growth of microorganisms. Some of the nutritional and physical requirements for growth are presented below.

a. Nutritional Requirements.

(1) *Energy.* All living organisms require a source of energy, either chemical or radiant. Life forms capable of utilizing radiant energy are designated as phototrophs. Life forms that

rely on the oxidation of chemical compounds for their source of energy are called chemotrophs.

(2) *Carbon.* All living organisms require carbon in the form of carbon dioxide (CO_2) or some organic carbon compound such as carbohydrates (sugars or starches) or protein-type materials. Carbon is the elemental basis of life. It is required for the organism to produce enzymes, amino acids, proteins, nucleic acids, and essentially all compounds needed for life.

(3) *Nitrogen.* All living organisms require nitrogen in some form for the formation of proteins and nucleic acids. Some organisms use atmospheric nitrogen, some require inorganic nitrogen compounds such as ammonia and nitrates, and still others must have more complex forms as amino acids or nitrates.

(4) *Sulfur and phosphorus.* All living organisms require sulfur and phosphorus. Some organisms require either organic or inorganic sulfur compounds, while others can utilize elemental sulfur. Phosphorus is usually supplied as phosphates and is the basis for the compounds which furnish energy for the organisms.

(5) *Trace metals.* All living organisms require metallic elements such as sodium, potassium, calcium, magnesium, manganese, iron, zinc, copper, phosphorus, and cobalt for normal growth. Some of these elements must be present in order to complete some chemical reactions which take place within the organism.

(6) *Vitamins.* All living organisms require vitamins and vitaminlike compounds for normal metabolic functions. Many organisms can produce all required vitamins, whereas some require vitamins as a preformed compound.

(7) *Water.* All living organisms require water. Water prevents drying of the organisms. Food must be in solution so that it can pass through the semipermeable-selective cytoplasmic membrane, and waste products must be in solution so that they can be eliminated from the cell. Water is the universal solvent, and its presence readily aids in the breakdown of complex food materials.

b. Physical Requirements.

(1) *Temperature.* Temperature is an important factor for the growth of microorganisms. Each species of organism grows best at a particular temperature or in an optimum temperature range. Pathogens of warmblooded animals develop best in the narrow temperature range

corresponding to the host's body temperature. At temperatures below or above this range, the organism functions with progressively less effectiveness until a temperature is reached at which growth no longer occurs. High temperatures can be lethal, while survival can often continue at low temperatures although metabolism is at a reduced rate.

(2) *Oxygen*. As with higher forms of life, all microorganisms require oxygen to live; however, they may differ markedly in respect to the sources from which they obtain oxygen. There are three types of microorganisms, according to their response to oxygen:

(a) *Aerobes*, which grow in the presence of free oxygen.

(b) *Anaerobes*, which grow in the absence of free oxygen, obtaining their oxygen from various chemical compounds.

(c) *Facultative anaerobes*, which grow in either the presence or absence of free oxygen. Most pathogenic microorganisms are facultative anaerobes because they can obtain their oxygen in either form.

(3) *pH*. For most microorganisms, the optimum pH (negative log of the hydrogen ion concentration) for growth lies between 6.5 and 7.5. There are a few microorganisms that can survive at the extremes of the pH scale, but for most species, the minimum and maximum pH fall between pH 4 and pH 9.

(4) *Light*. Most microorganisms do not require light for growth. They are destroyed by direct exposure to ultraviolet rays from the sun or from artificial sources. Consequently, growth occurs best in an environment protected from direct sunlight or in darkness.

10. Survival

a. *Encapsulation*. The formation of capsules, a process known as encapsulation, is a characteristic of many bacteria which favors their survival. The capsule is associated with the virulence of some pathogenic bacteria. Organisms that cause pneumonia and are encapsulated are highly virulent, whereas those which have no capsule are relatively avirulent. When observed in preparations made from animal tissues, anthrax bacilli are found to be encapsulated. The capsule appears to function as a bacterial defense against the activity of the phagocytic cells of the body. The capsule apparently originates from the outer layer of the cell membrane and consists of a thick,

colorless, translucent outer wall of gelatinous (protein), gummy (polysaccharide), or fatty material.

b. *Sporulation*. Sporulation (the formation of spores) is a protective mechanism favorable to the survival of some bacteria. All the organisms of the genera *Bacillus* and *Clostridium* are characterized by their ability to produce spores. Although spore formation is a protective mechanism, it is not always a response to unfavorable environmental conditions. Bacterial spores are more resistant to injurious or unfavorable influences (starvation, high and low temperatures, germicidal chemicals, drying, and oxidation) than are the growing or vegetative forms. The resistant spore might remain dormant for years without requiring nutrients or water and might survive under extreme ranges of temperature. It will then develop into an actively growing vegetative cell when conditions become favorable. Spore formation is not a method of reproduction inasmuch as each vegetative cell forms only a single spore, and each spore germinates to form a single vegetative cell. The spore is produced by a thickening of the cell wall and cytoplasmic membranes. The cytoplasm produces dipicolinic acid (a heat-resistant factor) which complexes with calcium ions located in the outer spore membranes. The mature spore is normally spherical or oval and is only a fraction of the size of the vegetative cell.

11. Reproduction

Depending on the microorganisms, reproduction may be asexual or sexual; however, the asexual process is more common.

a. *Asexual*. Asexual reproduction involves only one parent organism. Some of the common methods of asexual reproduction are as follows:

(1) *Binary fission*. In binary fission, the cell divides into two equal and identical parts, each of which develops into a new organism. When the cells are placed in a new environment, there is a period of adjustment or a lag phase during which the number of cells does not increase appreciably. If all essential factors are favorable and there is no opposition from the host, a small number of organisms might multiply within a few hours or days into numbers almost beyond comprehension. This type of reproduction is common to bacteria and rickettsiae.

(2) *Budding*. In budding, a small portion of the parent cell is pinched off and develops into a

new, actively growing individual cell. Yeasts, a type of fungus, usually reproduce by budding.

(3) *Fungal sporulation.* In fungal sporulation specialized reproductive cells, called fungal spores, are formed on the parent fungal plant. These spores germinate to produce mature fungal plants, which in turn produce more fungal spores. These spores are not a resistant mechanism and should not be confused with bacterial spores.

b. *Sexual.* Sexual reproduction is encountered among microorganisms. This method involves copulation of two cells with an interchange of genetic material and usually results in the formation of various types of spores.

c. *Replication.* Viruses are incapable of independent self-reproduction. To reproduce they must invade a suitable cell and make use of its metabolic processes. In replication (Template hypothesis), the infecting virus particle takes over the metabolic processes of the host cell and subsequent viruses are formed from host cell constituents.

12. Inhibition and Destruction

For the purposes of this manual, the term "inhibition" indicates arrest in growth or in multiplication (reproduction); "destruction" refers to death; "sterilization" is synonymous with destruction. Among microorganisms, these phenomena can be brought about by physical, chemical, or biological means. This paragraph is not concerned with those factors which influence the decay of biological aerosols created in the field but is concerned with the survival and/or growth of microorganisms in a laboratory.

a. Physical Means.

(1) *Temperature.* High temperature of varying degrees is effective in destroying microorganisms. Higher temperatures, or prolonged exposure to high temperatures, are required when dry heat is used than when moist heat is used. Direct exposure to flame and to steam under pressure may be used for sterilizing contaminated materials. Under regulated conditions, boiling water or flowing steam is effective when resistant species or spores are present. Some delicate organisms, however, do not survive even small temperature fluctuations in their environment. Rapid lowering of the temperature to subfreezing, accompanied by quick drying, tends to preserve the life of many microorganisms.

(2) *Desiccation.* Desiccation, or drying, is one of the oldest measures used to prevent spoil-

age of food by microorganisms. Some examples of drying are the production of jerked beef, dried fruits, powdered milk and eggs, and other dehydrated foods. In the absence of moisture, microorganisms cannot obtain nutrients by diffusion through the cell membrane; therefore, growth of the organism ceases. Vegetative organisms are particularly susceptible to drying, but spores are relatively unharmed. Drying might reduce the number of living organisms but cannot be relied upon for the destruction of all microorganisms present.

(3) *Starvation.* Growth can be inhibited and sometimes death can be induced when essential food materials are removed or rendered unavailable. All microorganisms require oxygen, carbon, nitrogen, and hydrogen in some usable form. If any one of these elements is eliminated or converted to an unusable form, the microorganism cannot maintain itself, grow, or reproduce, and will eventually die. Varying amounts of other materials are essential, depending on the kind of organism involved. Spores, as opposed to vegetative forms, can remain dormant for long periods without food. Spores might not be killed by starvation, but their germination or return to vegetative form can be prevented.

(4) *Light.* Ultraviolet rays from the sun or artificial sources quickly kill exposed microorganisms, but these rays have low penetrating powers and are of reduced effectiveness against microorganisms protected by thin liquid or dust films. Dust particles, clouds, smoke, and fog can filter out most of the ultraviolet radiation.

(5) *Filtration.* Microorganisms can be removed from air and liquids by various filtering devices. The efficiency of filtering processes depends not only on the kind of filter used but also on such factors as the size and number of organisms present, electrostatic charge, and rate of filtration. The larger organisms might be removed by filtration through asbestos pads, specially prepared membranes, filter paper, or unglazed porcelain when the pore sizes are too small to permit passage of the microorganisms. Some microorganisms, such as viruses, are so small that they cannot be removed by ordinary bacterial filters and require special filtration devices. Air that contains dustlike suspensions of microorganisms can be effectively filtered through thick layers of cotton or similar materials.

(6) *Osmosis.* The diffusion of a liquid through a semipermeable membrane (such as a cell membrane) separating two miscible (easily

mixed) solutions is known as osmosis. Although the diffusion proceeds in both directions, the flow of solvent is greater from the more dilute to the more concentrated solution. Living cells, including microorganisms, have semipermeable cell membranes; hence, when they are placed in high sugar or salt concentrations, the osmotic process removes water from them, resulting in inhibition of growth or even death. Common applications of this principle are the use of high concentrations of sugar to preserve foods, as jams and jellies, and the soaking of meats in brine. These measures are not effective for killing spores.

b. Chemical Means.

(1) *Disinfectants and antiseptics.* Many compounds are used to kill microorganisms or to inhibit their growth. *Disinfectants* are materials that kill pathogenic microorganisms. *Antiseptics* are substances that inhibit the growth and development of microorganisms but do not necessarily kill them. Some chemicals are powerful disinfectants, while others are only antiseptics. Among the common disinfectant and antiseptic preparations are mercuric chloride, silver nitrate, tincture of iodine, chlorine, phenol, cresol, formaldehyde, hydrogen peroxide, alcohol, hypochlorites, and some acids or alkalies. The vapors of propylene glycol, triethylene glycol, and ethylene oxide are also effective disinfectants and decontaminants. Proper concentration, temperature, and length of exposure are critical factors in the use of all these chemicals.

(2) *Chemotherapeutic agents.* These are chemical compounds used in the treatment of disease that affect the causative microorganism unfavorably without marked injury to the patient. They might kill the pathogen, inhibit its growth, or render it more susceptible to the defense mechanisms of the body. Among these substances are the arsphenamines, quinine, and the sulfonamides.

c. Biological Means.

(1) *Antibiotics.* Antibiotics are substances (chemical compounds), produced by some living microorganisms, that are selectively antagonistic to certain other living microorganisms. Antibiotics have the capacity to inhibit the growth of and even to kill various microorganisms. The microorganisms from which antibiotics are usually obtained are bacteria, yeasts, and molds. Some antibiotics, such as chloromycetin, originally obtained only from microorganisms can now be synthesized. No one antibiotic is inhibitory to all microorganisms, but each has a more or less specific inhibitory or growth-preventing action on particular species. Some have proved valuable in the treatment of diseases that are not responsive to chemotherapeutic drugs or antisera. Important antibiotics include penicillin, streptomycin, chlorotetracycline, and erythromycin. Antibiotics are not effective in the treatment of viral diseases.

(2) *Bacteriophages.* Bacteriophages are viruses which are parasitic to certain bacteria and might kill them. Like other viruses, bacteriophages multiply only within living cells. They are widely distributed in nature and are commonly present in the intestines of man and animals, especially those recovering from a bacterial disease. There are various strains of bacteriophages, each being specific for certain types of groups of bacteria; but many bacteria, including some of the more pathogenic, have no known bacteriophage. A very small amount of bacteriophage, when added to an actively growing, susceptible bacterial culture, will cause swelling, death, and disintegration of the bacterial cells within a few hours. At the present time, the bacteriophages have little application in the treatment of infectious diseases, but they are extremely useful in identifying, or "typing," some groups of bacteria.

Section III. KINDS OF MICROORGANISMS

13. Bacteria

a. *General.* Bacteria are single-celled, microscopic, plant-like organisms. These unicellular forms outnumber all other forms of microorganisms. It is estimated that the bacteria comprise 60 to 65 percent of the microorganisms. A few of the bacteria contain chlorophyll or other pigments and are capable of photosynthesis, but these are not of military significance. Bacteria occur nearly everywhere in nature. They are

carried by air currents from the earth's surface to the upper atmosphere. They are found in sediment in the bottom of the ocean at its greatest depths. The soil teems with them. They are in the air we breathe, in the water we drink, in the food we eat, in the bodies of living animals, and in dead or decaying organic matter. Fortunately for us, most microorganisms are harmless. Many bacteria are beneficial. They are used in the brewing industry, the drug industry, the cheese

industry, in the soil to improve fertility, and in petroleum production. Of approximately 2,000 identified species, only about 100 are known to be pathogenic. Most bacteria which infect man are selective human parasites, but some are primarily parasites of lower animals that are occasionally transmitted to man. Examples of these parasites of animals are the bacteria which cause anthrax and tularemia.

b. Classification. Bacteria are somewhat variable in form but may be classified according to shape into three main groups.

(1) *Bacilli; bacillus (sing.).* Rod shaped.

(2) *Cocci; coccus (sing.).* Round or spherical. The cocci are further classified into groups based on the manner in which they cling together after cell division.

(a) *Diplococci; diplococcus (sing.).* The diplococci divide in one plane and remain in pairs.

(b) *Streptococci; streptococcus (sing.).* The streptococci divide into one plane and cling together in chains.

(c) *Staphylococci; staphylococcus (sing.).* The staphylococci divide into irregular grapelike clusters.

(3) *Spirilla; spirillum (sing.).* Comma shaped or spiral. The spirilla are further designated according to specific shape.

(a) *Spirilla.* Rigid spiral.

(b) *Spirochetes.* Flexible spiral.

(c) *Vibrios.* Curved or comma shaped.

c. Structure. The cell is the basic structure of life, whether it be in the form of a single-celled bacterium or the human body composed of billions of cells. A typical bacterial cell can be divided into four main subdivisions—the cell wall, the cytoplasmic membrane, the cytoplasm, and the chromatin body. Other structures that bacteria might possess include flagella for movement; fimbriae (filamentous appendages) that function as organs of attachment; and capsules (a viscous layer covering the cell) that provide a protective coat, store food, act as a site for waste disposal, and, in some cases, increase the pathogenicity of certain pathogens.

(1) *Cell wall.* The bacterial cell wall is a rigid structure that gives shape to the cell. It constitutes 10 to 40 percent of the total weight of the organism. Estimates of the thickness of the cell wall range from 0.010 to 0.025 micron. Biochemical analysis has determined that the cell wall is composed of proteins, carbohydrates, and

lipids. Bacterial cell walls seem to be essential for bacterial growth and reproduction.

(2) *Cytoplasmic membrane.* Immediately beneath the cell wall is a fine membrane, approximately 0.005 micron thick, called the cytoplasmic membrane. The function of this delicate membrane is to control the passage of nutrients into and waste products out of the cell. Recent advances in electron microscopy have disclosed the presence of "primitive" intracellular membrane systems called mesosomes, extensions of the cytoplasmic membrane, that might function in various cytological and physiological phenomena.

(3) *Cytoplasm.* Within the cytoplasm, a number of subcellular bodies are present that perform various functions. Throughout the cytoplasmic area are densely packed bodies called ribosomes that function in protein synthesis. Also present are numerous granules and droplets that serve as food storage compartments and also probably function in other unknown capacities.

(4) *Chromatin body.* Bacterial cells differ from the higher plant and animal cells in that they do not have a well-defined nucleus and only possess one chromosome. The nuclear membrane is absent and the chromosome assumes various shapes. The chromosome is composed of deoxyribonucleic acid (DNA) that is responsible for directing heredity by a series of complex chemical reactions.

d. Motility. The round or spherical cocci forms are generally nonmotile. Some of the rod- and spiral-shaped bacteria have the power of independent movement. The motile organisms are propelled by the wave or screwlike motion of one or more flagella (long threadlike filaments) or, in some cases, by the undulation of the flexible body of the organism itself. Examples of motile organisms are the rod-shaped bacillus of typhoid and the corkscrew-shaped spirochete of syphilis.

e. Pathogenicity. Bacteria cause many of the common diseases of man, animals, and plants. Representative of the coccal (round) forms are the staphylococci, some of which cause boils and food poisoning; the streptococci cause scarlet fever and streptococcal sore throat; the gonococci cause gonorrhea; and the meningococci cause one form of meningitis. Representatives of the bacilli (rod-shaped) cause tuberculosis, anthrax, typhoid fever, bacillary dysentery, bubonic plague, brucellosis (undulant fever), and glanders. Cholera is caused by a comma-shaped vibrio and syphilis by a spiral or corkscrew-shaped spirochete. Diphtheria, tetanus, gas gangrene, and botulism are

caused principally by the toxins produced by bacillary organisms. Examples of diseases of plants caused by bacteria are bacterial wilt of corn and "soft rot" of vegetables. Bacteria have primary military potential as anti-personnel agents.

14. Rickettsiae

a. General. The rickettsiae are intracellular, parasitic micro-organisms that are considered intermediate in size between the bacteria and viruses. They resemble the bacteria in shape and resemble the viruses in their strict growth requirements for living host cells. Most rickettsiae are parasites, primarily of lower animals and arthropods. Rickettsiae are transmitted to man and animals by such vectors as ticks, lice, fleas, and mites. The rickettsiae have a selective affinity for specific types of cells of the human and animal body. As they require living tissue for reproduction, they are considered obligate parasites.

b. Form and Structure. The rickettsiae are from 0.3 to 0.5 micron in length and about 0.3 micron in diameter. Like bacteria, they might assume round, paired, or short rod-shaped forms. They are usually capable of being removed by bacterial filters and are gram-negative, nonmotile, and nonsporulating. They are easily killed by heat, dehydration, or disinfectants. Studies with an electron microscope reveal a homogeneous or slightly granular interior structure resembling that of bacteria.

c. Pathogenicity.

(1) The rickettsial diseases of man may be classified, on the basis of certain characteristics, into the following groups: typhus fever, spotted fever, scrub typhus, Q fever, and other miscellaneous diseases. Of these, typhus fevers, spotted fevers, and scrub typhus are clinically similar in that they are accompanied by fever, skin rashes or dark blotches, and central nervous system disturbances.

(a) The typhus fevers include classic epidemic (human) typhus, an acute louse-borne infectious disease; endemic (murine) typhus, a milder type of typhus transmitted to man from infected rats by flea bites; and Brill's disease (recrudescence typhus), a relatively mild recurrence of epidemic louse-borne typhus fever in which the rash is frequently absent.

(b) The spotted fever group includes Rocky Mountain spotted fever of the United States, a relatively severe disease transmitted to

man by the bite of a tick. Other tick-borne or mite-borne diseases of the spotted fever group are Brazilian spotted fever, Tobia fever of Colombia, boutonneuse fever of the Mediterranean area, South African tick fever, North Queensland tick fever, rickettsialpox, maculatum disease of the Gulf Coast of the United States, and possibly some of the tick-borne rickettsial diseases of India and Russia.

(c) Scrub typhus (tsutsugamushi disease), a moderately severe disease, is transmitted to man by the bite of a mite.

(d) Q fever is an acute, febrile illness which differs from other rickettsial diseases in that it may or may not be transmitted by the bite of an arthropod vector and does not produce a skin rash. This disease can be acquired by ingestion or inhalation of contaminated material. Since Q fever can be introduced through the respiratory tract, it may become the most common of all rickettsial diseases.

(e) Other rickettsial diseases of man are trench fever and Bullis or tick fever of Texas.

(2) A rickettsial disease of animals is "heartwater," or veldt disease, a tick-borne disease fatal to cattle, sheep, and goats in South Africa.

(3) There are no known rickettsial diseases of plants.

(4) Rickettsiae have primary military potential as antipersonnel agents.

15. Viruses

a. General. The group of microorganisms called viruses are all obligate parasites that live in the cells of their selected hosts. Viruses are so small they will pass filters which stop bacteria and rickettsiae. About 60 percent of all infectious diseases are caused by viruses. The mystery surrounding viruses lies in the fact that being composed of only ribonucleic acid (RNA) or deoxyribonucleic acid (DNA) and a protein coat, the virus does not contain most of the components found in ordinary cells. Once a virus enters a living cell, it is capable of replicating itself by taking over the metabolic processes of the invaded cell. Viruses have been described as "Super Salesmen" because they persuade the host cell to manufacture virus protein and RNA or DNA rather than cell constituents required by the host. Cells infected with viruses show one of the following responses: degeneration and death, transformation to a neoplastic state, or survival without transformation but with evidence of the presence of one or more

viral components. Diseases of viral origin do not respond to treatment with antibiotics.

b. Form and Structure. The viruses range in size from about 0.01 to 0.27 micron across their greatest dimension as determined by studies employing filtration, the electron microscope, and the ultracentrifuge. Because of their extremely small size, not all viruses have been observed; however, globular, crystalline, square, rectangular, and spherical shapes have been described. It is questionable that all viruses are essentially of the same nature. The very small forms, like the crystalline mosaic viruses of tobacco and cucumbers, might be inanimate, while the larger ones are among the smallest microorganisms.

c. Pathogenicity. The viruses are responsible for many important diseases of man, animals, and plants. Human diseases caused by virus include poliomyelitis, rabies, smallpox, yellow fever, encephalitis, mumps, measles, chickenpox, influenza, and the common cold. Important animal diseases produced by viruses are rinderpest and foot-and-mouth disease of cattle; hog cholera and African swine fever (similar to hog cholera but more acute); distemper and rabies of dogs; and fowl plague and Newcastle disease of poultry. Typical viral infections of plants are tobacco and cucumber mosaic diseases and curly top disease of sugar beets. Viruses have primary military potential as antipersonnel agents.

16. Fungi

a. General. The fungi are unicellular or multicellular members of the plant kingdom, whereas bacteria are unicellular. Fungi include molds, mildews, smuts, rusts, mushrooms, toadstools, puffballs, and yeasts. Fungi produce numerous serious plant diseases, but relatively few important dis-

eases of man or animals are attributable to this group of organisms. Even though fungi destroy foods, fabrics, and wood, they do serve a useful purpose in nature by helping to decompose dead organic matter in soil. The products of many fungi are useful in industry and medicine; examples are yeast, ergot, penicillin, and streptomycin.

b. Form and Structure. The cells of most fungi are larger than bacteria, ranging from 3 to 50 microns in size. They are usually rod shaped and arranged end-to-end in strands or filaments. Yeast cells are usually oval and might appear singly, in clumps, or in long chains. Although molds and yeasts resemble bacteria in many respects, they are more complex structurally and physiologically and are considered to be more highly evolved members of the plant kingdom. Some representatives of the fungi which appear to have potential value as biological agents will be discussed separately in this manual.

c. Pathogenicity. Fungal diseases in humans are generally less acute than those produced by other organisms and are for the most part low-grade chronic infections such as ringworm and "athlete's foot." However, some fungi are capable of producing serious diseases in man, examples of which are histoplasmosis and coccidioidomycosis. Coccidioidomycosis is an infection which might be localized and relatively mild, or systemic, malignant, and rapidly fatal. Other fungal diseases of man are favus, cryptococcosis, thrush, blastomycosis, and sporotrichosis. Fungi produce many serious diseases in plants such as brown spot of rice; rice blast; late blight of potato; cereal rusts; southern blight of sugar beets, white potatoes, and other root crops; smuts; ergot on rye grain; and many others. Fungi have military potential primarily as antiplant agents.

CHAPTER 3

INFECTION AND IMMUNITY

17. Infection

Infection is defined as the invasion of a host by microorganisms, which then grow and reproduce. Note that this definition in no way refers to the presence or absence of disease or the number of invading organisms. Pathogenicity is the ability of an organism to produce disease. Generally, most pathogenic organisms, whether they are bacteria, rickettsiae, or viruses, must increase in number to produce sufficient quantities of toxins or harmful enzymes to disrupt the physiochemical behavior of the body. Once infection has been established, *disease* can result.

a. Disease. Disease is defined as any departure from a normal state of health. The obvious signs of disease, such as malaise, inflammation, and pain, are indicative of more deep-seated disturbances such as disrupted cellular metabolism or death of the cells.

b. Incubation Period. Following the invasion of a pathogenic organism into the body, there is a lapse in time before symptoms of disease are seen; this lapse in time is the *incubation period*. The incubation period, therefore, can be defined as the time lapse between entry of the pathogen and the onset of the first symptoms of the disease. The length of the incubation period will vary greatly, depending upon the particular species of the pathogen, number of pathogens, and resistance of the host. The incubation period probably would be considered by the enemy if biological agents are to be disseminated because casualties will not result until the incubation period has passed.

c. Infection Without Disease. Some organisms will survive, grow, and reproduce within the body without disease.

(1) The organism *Escherichia coli* is a common inhabitant of the intestinal tract of man. Technically, the intestinal tract is infected, but normally a disease does not result. Numerous organisms will also grow and survive within the mouth of man without causing disease.

(2) During the incubation period, the microorganisms are growing and multiplying. The host has been infected but is not considered diseased until signs or deviations from normal are observed.

(3) The carrier state is a condition in which the infected individual shows no symptoms but actually is infected and capable of transmitting the infective organisms to susceptible individuals. The most famous case of this type of infection is that of Typhoid Mary who infected many individuals and households before her existence as a "carrier" of typhoid fever was established. This condition is not thought to be of importance in the military employment of biological agents.

(4) The subclinical, or nonapparent, infection is closely related to the carrier state. In subclinical cases, symptoms are temporarily or intermittently hidden, or infection is detected only by resorting to laboratory procedures. A few subclinical cases might occur following an attack employing living microorganisms.

18. Factors Involved in Infection

Some factors involved in infection are portals of entry, infective dose of the pathogen, and virulence of the infecting organism.

a. Portals of Entry. The places where pathogens gain entry into the body are known as portals of entry. The three important portals of entry are the skin, respiratory tract, and the digestive tract.

(1) The body is better prepared to resist invasion by microorganisms at certain locations in the body. If the same microorganisms gain entry to the body at a different location, disease might result. An example of this is the high number of intestinal organisms (*Escherichia coli*) which are normally present within the intestines and produce no disease. However, if but a few of organisms gain entrance into the genitourinary tract, a serious infection of the bladder and/or kidneys can result.

(2) The typical symptoms associated with a particular pathogen might be profoundly altered following entry of the organism through an unusual portal of entry. This might greatly add to the difficulty in arriving at a proper diagnosis and thus in providing proper treatment.

(3) Entry of the organism through an unusual portal of entry might change the severity of the disease *Francisella tularensis*, when introduced through a scratch on the skin of the finger or hand is usually localized in the lymph nodes of the arms and axillae, rarely invades the bloodstream, and has a mortality rate of about 5 percent. However, the same organism introduced into the tissues by the bite of a deer fly or tick readily invades the bloodstream, producing a septicemia which has a mortality rate of approximately 40 percent.

(4) The respiratory system of the body is much more susceptible to invasion by microorganisms than are the other portals of entry because of the large surface area of the lungs, the one-cell layer thick alveolar sacs, and the tremendous vascular supply. Many organisms that enter the respiratory tract can easily penetrate the alveolar sacs, enter the bloodstream, and rapidly spread throughout the body rather than localizing in one area. The respiratory system would, therefore, appear to be the portal of entry most susceptible to the intentional aerosol dissemination of pathogenic microorganisms.

b. Infective Dose. The second factor of infection is the infective dose—the number of microorganisms required to establish infection.

(1) *Number of organisms.* It has already been pointed out that the normal body is capable of combating and overcoming the average number, or "street dose," of microorganisms that it normally encounters from natural exposure. However, if massive overdoses of pathogens are encountered, perhaps as a result of a biological agent aerosol, the body would be unable to prevent their successful invasion.

(2) *Condition of the host.* There are many factors which determine the host's ability to resist infection. Certain physiological factors, such as body temperature and diet, contribute to susceptibility. Body temperature is an important factor in the reproduction and survival of microorganisms in the body and might explain some instances of man or animal being immune to some pathogens when the other is susceptible. The presence, absence, or imbalance of certain

essential metabolites might determine the pathogenicity of a particular organism. Deficiencies of proteins and vitamins might reduce the normal resistance to infections with bacteria and rickettsiae, but there is experimental evidence that these same deficiencies might increase the resistance to viral infections. Certain physiological or pathological characteristics of the host, such as debilitation resulting from fatigue, alcoholism, irradiation, aging, or overexposure to extreme temperatures, also play an important role in determining the susceptibility of an individual to infections.

c. Virulence. Virulence is the relative pathogenicity of a microorganism or a measure of the severity of the disease that a pathogen is able to produce. There are two contributing factors to virulence—invasiveness and toxicity.

(1) *Invasiveness.* This is the relative ability of a microorganism to break down the body's defenses and spread throughout the host. Pathogenic organisms possess many enzymes and other proteins which allow them to spread rapidly. Some examples of these compounds are:

(a) *Streptokinase.* Certain hemolytic streptococci, clostridia, and staphylococci produce the enzyme streptokinase, which activates the proteolytic enzyme plasminogen that dissolves the fibrin network produced by the tissues in response to an injury. The fibrin network is a body defense mechanism which provides a barrier against the spread of infection. The ability to dissolve this fibrin, therefore, enhances invasiveness of the bacterium.

(b) *Hyaluronidase.* Hyaluronidase is an enzyme produced by some clostridia, streptococci, pneumococci, and certain micrococci. This enzyme increases tissue permeability by hydrolyzing the jellylike hyaluronic acid that is the cementing substance between cells and constituents of the body's connective tissue. Once this material has been liquefied, new areas of host tissue are open to infection.

(c) *Leucocidin.* During the inflammation period, some leukocytes are drawn to the infected area by the process of chemotaxis where they phagocytize the pathogens. However, some pathogenic organisms can produce the chemical compound leucocidin, which will kill the phagocytes directly or cause the cell to dissolve.

(2) *Toxicity.* Toxicity is defined as the quality of being poisonous. Once a toxin-producing pathogen has entered the body, the various toxins produced can disrupt the delicate physiochemical

balance within the body's cells and disease can result. These toxins can be broadly classed into two types, depending upon their chemical composition, resistance to heat, and method of release from the pathogen.

(a) *Exotoxins*. Exotoxins are proteins of varying molecular weight. Some of these are enzymes. The exotoxin is a normal part of the pathogen's metabolism or might be part of the organism's Cytochrome B system; for example, diphtheria toxin. *Clostridium perfringens* is capable of producing 10 different exotoxins. One is the enzyme lecithinase (alpha toxin) which attacks red blood cells. Others include the kappa toxin, which is hemolytic, and the beta, epsilon, and iota toxins which cause necrosis of tissue. Exterotoxins are exotoxins which are produced by certain staphylococci. Their primary action is upon the digestive tract. These toxins produce severe nausea, vomiting, and diarrhea, but the possibility of death is remote. Man normally acquires these heat-stable toxins following ingestion of contaminated food.

(b) *Endotoxins*. Endotoxins, a protein-polysaccharide-lipid complex, are synthesized by the cytoplasmic membrane or by the mesosomes (i.e., intracellular membrane system) and become a part of the cell wall of the microorganism. Since this toxin is part of the cell wall, it can only be released upon death and autolysis of the cell. It is presently thought that the toxicity of this toxin depends upon the particle size of the cell wall. *Rickettsiae prowazekii*, which cause typhus fever, produce an endotoxin which causes the rapid destruction of the red blood cells and increases the permeability of blood vessels, resulting in hemorrhage.

19. Body Defenses Against Disease

The body possesses two types of defense against pathogenic organisms. These are genetic (or natural) nonspecific immunity and acquired immunity. Immunity is the power which an individual possesses to resist or overcome an infection.

a. *Genetic Immunity*. Genetic (or natural) nonspecific immunity is present at birth; exposure to a microorganism is not required. The following could be considered as examples—physical barriers, phagocytic cells, and biochemical resistance factors.

(1) *Physical barriers*. The physical barriers are the body's first line of defense and consist of the skin and mucous membranes. The skin when unbroken forms a tough coat over the exterior of

the body, which is quite resistant to infection. The saltiness and relative dryness of the skin also enhance the protection afforded by it. Certain fatty acids in skin secretions are bactericidal and fungicidal. When microorganisms landing on the skin do not find a favorable environment for growth, they perish. The mucous membranes are a continuation of the skin and are found lining those body cavities communicating with the exterior. The membranes produce a moist, sticky substance, known as mucus, which tends to trap and hold microorganisms which come in contact with it. The secretions of the digestive tract are acidic in some portions and alkaline in others; this is deleterious to certain pathogenic organisms.

(2) *Phagocytic cells*. A part of the body's second line of defense is cellular. If microorganisms succeed in passing the physical barriers and enter deeper tissues, they are then attacked by phagocytic cells which attempt to engulf and digest them. Phagocytes (the term is derived from Greek and means "to eat") are defined as cells that ingest microorganisms, cells, or foreign particles. There are two kinds of phagocytes—free and fixed. Free phagocytes include certain leukocytes (white blood cells) of the blood and "wandering" macrophages of the tissues. Fixed phagocytes occur abundantly in the liver, spleen, lymph nodes, bone marrow, and connective tissue.

(3) *Biochemical resistance factors*. Biochemical resistance factors, some of which are discussed below, also constitute a part of the second line of defense.

(a) *Lysozymes*. Lysozymes are mucolytic enzymes that attack bacteria and cause them to dissolve. This enzyme hydrolyzes the acetylaminopolysaccharide constituent of the cell wall in both gram-positive and gram-negative bacteria, thereby killing the cell. This substance is present in body tissues, fluids, and phagocytes.

(b) *Polypeptides*. Basic polypeptides such as spermine apparently combine with nucleoproteins and other negatively charged surface constituents of some bacteria and viruses and disrupt important cell functions, resulting in death of the pathogen. Spermine occurs in many tissues of the body.

(c) *Properdin*. Properdin is a high molecular weight protein (10^6) found in the normal bloodstream. When combined with complement (a mixed globulin found in plasma that enhances phagocytosis) and magnesium ions, it kills many gram-negative bacteria and neutralizes several viruses. Properdin is not removed by antigen-

antibody complexes and is not involved in the blood-clotting mechanism.

(d) *Interferon*. Interferon is a low molecular weight protein (20,000 to 30,000) which is produced in cells infected by viruses. This protein causes antiviral protein (protein X) to be produced in cells surrounding the infected cell which then inhibits further viral RNA or DNA synthesis in these cells. This mechanism does not appear to neutralize viruses in the bloodstream or to prevent their penetration into body cells. It is not specific and exerts its inhibitory effect on many different viruses. Interferon production starts immediately at the onset of a viral infection. Effective quantities are available many days before protective antibodies are produced. Protein X produces its effect inside body cells where viral antibodies cannot penetrate. Research is being conducted to determine the feasibility of artificial interferon stimulation by vaccination with a harmless form of nucleic acid.

b. *Acquired Immunity*. Acquired immunity is dependent upon the presence of antibodies. Antibodies in the blood react with and destroy or neutralize invading pathogens before they have a chance to do damage; antibodies are the body's third line of defense. Antibodies, which are produced by specialized cells, are primarily gamma globulins (average molecular weight 160,000). These gamma globulins are formed in response to an antigenic stimulus, and react specifically with the type of antigen that originally stimulated their production. These reactions are effected through the formation of weak hydrogen bonds of electrostatic forces. There are two types of acquired immunity—active and passive.

(1) *Active acquired immunity*. Active acquired immunity results in an individual when the antibody production takes place in his own body. Active acquired immunity lasts longer than passive acquired immunity because the individual's body is actively producing the antibody; but it takes longer to develop because the individual has to be stimulated before antibody production begins.

(a) *Natural active acquired immunity*. Natural active acquired immunity results from natural causes. An example of this is the immunity which develops after having the disease of chickenpox. The natural immunity developed after recovery from this disease is long lasting. This is also true of recovery from other diseases whereby the individual concerned produces his own antibodies. The individual develops a certain amount

of natural immunity which provides some protection against subsequent contacts.

(b) *Artificial active acquired immunity*. Artificial active acquired immunity results when attenuated or killed organisms or toxoids are introduced into the body. With this type of immunity, the individual is also actively engaged in the production of antibodies against a stimulus; i.e., the vaccine. Vaccinations against yellow fever and typhoid fever produce this type of immunity.

(2) *Passive acquired immunity*. Passive acquired immunity results from antibodies, produced by another individual or an animal, which are naturally or artificially transferred to an individual.

(a) *Natural passive acquired immunity*. Natural passive acquired immunity is the type of immunity obtained by infants from their mothers while still in the uterus. Depending upon past experience with a given disease, the mother will have antibodies present within her bloodstream. These antibodies are transferred from the maternal circulation to the fetal circulation and thus become a part of the blood supply of the newborn infant. This type of immunity is relatively short lasting, protecting the infant for a period of 2 to 6 months, depending on the specific infection or disease under consideration.

(b) *Artificial passive acquired immunity*. Artificial passive acquired immunity is the type of immunity acquired from antibodies produced in the body of an individual or an animal and transferred by artificial means to another who is in need of rapid protection. For example, in the commercial production of antisera, the toxin causing the disease of tetanus may be treated by heat or by chemical means to weaken it; it is then referred to as a toxoid. A horse is then inoculated with the toxoid in increasing doses until it has developed a strong immunity against the tetanus toxoid. The antibody produced is referred to as the antitoxin (an antibody against a toxin). A certain amount of blood is taken from the horse, and that portion containing the antitoxin is extracted, purified, and held ready for use. When an individual or animal is in need of quick protection against the toxin of tetanus, the antitoxin produced by the horse is used (immune serum or antisera). Compared to active immunity, artificial passive acquired immunity is of short duration.

(c) *Effectiveness of acquired immunity*. Acquired immunity is not 100 percent protective. Immunity acquired as the result of antibody production might be overcome by a massive number

or increased infective dosage of microorganisms. Although acquired immunity is not 100 percent

absolute, it must not be discounted. It will surely lessen the severity of a disease.

CHAPTER 4

POTENTIAL BIOLOGICAL ANTIPERSONNEL

Section I. INTRODUCTION

20. General

The information presented in this chapter and in the subsequent chapters on antianimal agents, antiplant agents, and antimateriel agents can be found in open professional or scientific literature. The information is presented in this manual in summarized form to acquaint military personnel with the identity and some of the characteristics of certain pathogenic agents and diseases which appear to have potential military applications. The choice of diseases discussed in this manual is strictly arbitrary and is not based in any part on friendly or enemy capabilities, potentials, or intelligence. Diseases were chosen on the basis of general population susceptibility, natural occurrence, historical significance, and general interest. The index to this manual has been devised to facilitate immediate location of information by the use of many cross-references and by listing important diseases and microorganisms in groups as well as alphabetically. *For example*, any important disease may be found under the heading *Disease* and also in its alphabetical order. Table 1, at the end of this chapter, summarizes the potential biological antipersonnel agents.

21. Objectives

Biological antipersonnel agents are those which are effective directly against man and are selected on the basis of their ability to cause death or disability through disease. While these agents might be employed against selected individuals, their main value appears to lie in producing mass casualties over large areas with resultant physical and psychological effects that could weaken or destroy our ability to resist aggression.

22. Types

The most promising potential biological antiper-

sonnel agents are found among the bacteria, rickettsiae, viruses, and fungi.

a. Bacteria. Naturally occurring bacteria are responsible for many serious human diseases. Bacteria also offer a wide variety of choice as biological antipersonnel agents with respect to feasibility of production, stability, viability, virulence, portals of entry, casualty-producing effects, modes of transmission, and methods of dissemination. Included among important bacterial diseases of man are scarlet fever, meningococcal meningitis, gonorrhea, diphtheria, tuberculosis, anthrax, tetanus, certain pneumonias, typhoid and paratyphoid fevers, the bacillary dysenteries, melioidosis, plague, cholera, tularemia, brucellosis (undulant fever), glanders, syphilis, yaws, gas gangrene, and Salmonella food poisoning.

b. Rickettsiae. The rickettsiae are less prevalent and produce fewer diseases than bacteria and viruses; nevertheless, they cause important diseases such as Q fever, typhus fever, and the spotted fevers. However, being strict obligate parasites, the rickettsiae are more difficult to produce in quantity than bacteria because they require living cells for growth; and, in addition, they are normally dependent on arthropod vectors for transmission.

c. Viruses. Viruses cause many important human diseases but present much the same difficulties of production as the rickettsiae. Important human diseases caused by viruses are influenza, poliomyelitis (infantile paralysis), rabies, smallpox, yellow fever, dengue fever, equine encephalomyelitis, infectious hepatitis, mumps, and measles.

d. Fungi. Coccidioidomycosis, histoplasmosis, and nocardiosis are fungal diseases that affect man.

Section II. ZOONOSES

23. General

Zoonoses are diseases which occur primarily in animals but that can be transmitted naturally to humans. Diseases such as anthrax, tularemia, brucellosis, and rabies are normally thought of as animal diseases. These diseases occur infrequently in humans as a result of natural transmission such as a dog bite, insect bite, or cut in the skin.

24. Susceptibility

The zoonoses lend themselves as potential biological antipersonnel agents because the average person has very little acquired immunity to these diseases since he does not normally come in contact with them. Without immunity to these

diseases, man's resistance is low and his susceptibility is high. Some vaccines are frequently used in areas where these diseases are found. Other vaccines are for high risk personnel only, such as laboratory technicians, veterinarians, woolsorters, tanners, and meat packers. Many diseases belong to the zoonoses, such as anthrax, brucellosis, plague, tularemia, typhus, Rocky Mountain spotted fever, Q fever, encephalitis, yellow fever, Rift Valley fever, and rabies. These diseases have potential not only as antipersonnel agents but also as antianimal agents. The fact that medical and government authorities will not permit treatment of animals for many of the zoonotic diseases, but require that the animals be destroyed, enhances the potential of the zoonoses as anti-animal agents.

Section. III. BACTERIA

25. *Bacillus Anthracis* (Anthrax)

a. Description. *Bacillus anthracis* is a rod-shaped, gram-positive, aerobic, sporulating microorganism; the spores constitute the usual infective form.

b. Disease Produced. Anthrax may appear in three forms in man: cutaneous, pulmonary, and intestinal. The cutaneous or skin form of anthrax, also referred to as malignant pustule or malignant carbuncle, occurs most frequently on the hands and forearms of persons who work with infected livestock. Cutaneous anthrax is characterized by swelling and ulcerated sores at the site of infection. Sometimes this local infection will develop into systemic infection. The pulmonary form, known also as woolsorters' disease, is an infection of the lungs contracted by inhalation of the bacterial spores. It occurs mainly among workers who handle contaminated hides, wool, or furs. The intestinal form, which is rare in man, is contracted by ingestion of insufficiently cooked meat from infected animals.

c. Sources of Infection. Cattle, sheep, goats, and horses are the chief animal hosts; but other animals might also become infected. The disease can be contracted by the handling of contaminated hair, wool, hides, flesh, blood, and excreta of infected animals and from products manufactured from infected animals, such as bone meal.

d. Modes of Transmission. Transmission is

through scratches or abrasions of the skin, wounds, inhalation of spores, or eating improperly cooked meat. Flies can serve as mechanical vectors.

e. Incubation Period. The incubation period is from 1 to 7 days. It is usually less than 4 days and may be less than 24 hours in pulmonary cases.

f. Susceptibility and Resistance. Presumably all human populations are susceptible. Recovery from an attack of the disease may be followed by some degree of immunity.

g. Prevalence. Anthrax is sporadic in man and is associated only with animal infections or handling of infected hides and furs.

h. Mortality. In man, the mortality rate of untreated cutaneous anthrax ranges up to 25 percent; in pulmonary cases, it might approach 100 percent. The rare intestinal cases of anthrax are usually fatal.

i. Immunization. Immunization measures have been developed and are presently being evaluated in industrial situations.

j. Treatment. Cutaneous anthrax can be treated effectively with some antibiotics, including penicillin, aureomycin, terramycin, and chloromycetin; with sulfadiazine; and with immune serum. Similar treatment or treatment with immune serum for pulmonary and intestinal infections

may be useful in the very early stages, but is of little value after the disease is well established.

k. Epidemicity. Anthrax is not contagious from man to man. Control of the disease is accomplished by prompt disposal of infected carcasses by burning or deep burial and by decontamination of animal products.

l. Stability. The spores are very stable and may remain alive for many years in soil and water, while the vegetative form is quite unstable. Spores will resist sunlight for several days. Steam under pressure, or exposure to dry heat above 284° F. for 1 hour, is necessary to kill spores. Effective decontamination can be accomplished by boiling contaminated articles in water for 30 minutes or by using some of the common disinfectants. Chlorine is effective in destroying spores and vegetative cells.

26. *Brucella* Group (Brucellosis)

a. Description. In this group three closely related organisms are included: *Brucella melitensis*, *Brucella abortus*, and *Brucella suis*. All are non-motile, nonsporulating, gram-negative, rod-shaped bacilli.

b. Disease Produced. Brucellosis, or undulant fever in man, is a general infection characterized by irregular prolonged fever, profuse sweating, chills, pain in joints and muscles, and fatigue. The illness lasts for months, sometimes for years, and may be caused by any one of the three related organisms. *Brucella abortus* is the cause of contagious abortion in cattle; the organism also has been reported in horses, sheep, rabbits, and guinea pigs. *Brucella melitensis* is the cause of brucellosis in goats and sheep; *Brucella suis* is the cause of abortion in swine and has been found in cattle. *Brucella melitensis* and *Brucella suis* are more virulent for man than is *Brucella abortus*.

c. Sources of Infection. *Brucella* organisms may be found in tissues from infected goats, cattle, and swine, and in milk and dairy products.

d. Modes of Transmission. These diseases are transmitted to man by ingestion of unpasteurized contaminated milk or other dairy products, uncooked or improperly cooked meats, and food and water contaminated by excretions of infected animals. Infection has also occurred by inhalation and by accidental inoculation among laboratory workers.

e. Incubation Period. The incubation period is

difficult to ascertain. It is felt that for human infections, it is 5 to 21 days, but occasionally several months.

f. Susceptibility and Resistance. Susceptibility is variable as evidenced by the wide variation in clinical illness and the presence of mild or non-apparent infections. The duration of acquired immunity is uncertain.

g. Prevalence. Brucellosis is prevalent in most areas of the world where cattle, goats, and swine are raised. Infection of man occurs more often in males than in females because of the increased exposure rate in persons working with these animals or their products; it occurs with equal frequency in males and females using unpasteurized milk of cows or goats.

h. Mortality. The mortality rate of untreated cases averages less than 2 percent with *Brucella abortus* and *Brucella suis* and 3 to 6 percent with *Brucella melitensis*.

i. Immunization. Immunization methods for man are being evaluated. Immunization of calves is effective as a control measure in cattle.

j. Treatment. The course of the diseases may be shortened by appropriate treatment with antibiotics, particularly by a combination of dihydrostreptomycin and the tetracyclines. However, some cases are resistant to all forms of therapy. The relapse rate is high.

k. Epidemicity. The disease is not communicable from man to man. Epidemics could result from wide-scale consumption of unpasteurized contaminated dairy products.

l. Stability. *Brucella* organisms will remain alive for weeks in water, unpasteurized dairy products, and soil; they are very resistant to low temperatures. Contaminated materials are easily sterilized or disinfected by common methods. Pasteurization is effective for contaminated dairy products.

27. *Francisella tularensis* (Tularemia)

a. Description. *Francisella tularensis* is a small, gram-negative bacterium often varying in size and shape. It is nonmotile and nonsporulating.

b. Disease Produced. Tularemia is also known as rabbit fever and deer fly fever. It is a fatal septicemic (blood poisoning) disease of wild rodents that may be accidentally communicated to man. In man, tularemia is characterized by the

sudden onset of chills, fever, and prostration, with a tendency for pneumonia to develop. Tularemia may demonstrate enlargement of the regional lymph glands with or without an ulcerative lesion at the site of infection. Moreover, this disease may be accompanied by typhoid-like symptoms.

c. Sources of Infection. Wild rabbits, hares, deer flies, ticks, and many other animals (including the woodchuck, opossum, tree squirrel, skunk, cat, deer, fox, hog, sage hen, and some snakes) are sources of infection.

d. Modes of Transmission. Transmission is by infection through the skin, eyes, or lungs from handling infected animals, as in skinning or dressing the animals (usually rabbits) or performing autopsies; by bites of infected flies and ticks; by eating insufficiently cooked rabbit meat; or by drinking contaminated water. Laboratory infections are not infrequent.

e. Incubation Period. The incubation period is from 1 to 10 days, usually about 3 days.

f. Susceptibility and Resistance. All ages are susceptible, and recovery from an attack is followed by lasting immunity.

g. Prevalence. The disease is present throughout North America and in many parts of continental Europe, Russia, and Japan. It occurs in every month of the year in the United States.

h. Mortality. The mortality rate can be as high as 30 to 40 percent for untreated cases.

i. Immunization. Vaccination, using a living attenuated organism, greatly reduces the severity of the disease and may prevent infection.

j. Treatment. The antibiotics, particularly streptomycin, aureomycin, and chloromycetin, are effective.

k. Epidemicity. The disease is essentially sporadic, but may be epidemic when modes of transmission (*d* above) are prevalent. It is not transmitted directly from man to man.

l. Stability. The organism remains viable for weeks in water, soil, carcasses, and hides. It is resistant to temperatures of freezing and may remain viable for years in frozen rabbit meat. It is easily killed by heat at 113° F. or above for a few minutes or by 0.5 percent phenol in 15 minutes.

28. *Pasteurella Pestis* (Plague)

a. Description. *Pasteurella pestis* is a rod-

shaped, nonmotile, nonsporulating, gram-negative, aerobic bacillus.

b. Disease Produced. Plague, or black death, occurs as three primary clinical types in man: bubonic, septicemic, and pneumonic. Another type of plague, sylvatic plague, is an infectious disease of wild rodents, including rabbits. Plague is transmissible to man by the bite of an infected flea or from man to man by the respiratory route. In general, plague is characterized by a rapid clinical course with high fever, extreme weakness, glandular swelling, and pneumonia. Hemorrhages in the skin and mucous membranes may or may not occur.

(1) Bubonic plague, the most common type, is transmitted from rats to man by the bite of an infected flea; the disease is perpetuated by the rat-flea-rat transmission cycle. The flea bites are usually on the lower extremities. The bacilli spread rapidly through the lymphatic system, causing enlarged lymph nodes (buboes) in the groin. The bacilli may escape from the nodes, invade the bloodstream, and produce a generalized often fatal infection. The spleen, lungs, and meninges may be affected.

(2) Pneumonic plague, which may result from the septicemic form or from inhalation of the organism, spreads rapidly until the entire lung area is involved in a hemorrhagic pneumonic process. Untreated pneumonic plague is usually fatal.

c. Sources of Infection. Infected rodents and human patients with pneumonic plague are sources of infection. The primary source of the disease is the domestic rat; another, less important, source is the wild rodents, including ground squirrels, pack rats, and harvest mice of the United States and various species of wild rodents in other parts of the world. In rare instances, rabbits in the western United States are sources of infection.

d. Modes of Transmission. Bubonic plague generally is transmitted to man by the bites of fleas from infected rats and other rodents. Pneumonic plague is transmitted directly from man to man by droplet infection.

e. Incubation Period. The incubation period is from 2 to 6 days for bubonic plague and 3 to 4 days for pneumonic plague.

f. Susceptibility and Resistance. Susceptibility is general, particularly to the pneumonic form. Recovery is followed by temporary immunity.

g. Prevalence. The human disease is rare in North America and the island possessions of the United States. Occasional cases of the bubonic type occur west of the Mississippi River from bites of fleas from infected wild rodents. The disease has foci of infection in various parts of the world, particularly in Asia.

h. Mortality. Untreated bubonic plague has a mortality rate of 25 to 50 percent, while untreated pneumonic plague kills from 90 to 100 percent of its victims. Treatment can reduce these figures markedly.

i. Immunization. Immunization with killed bacterial vaccines is protective when administered in three doses at monthly intervals; repeated stimulating doses are necessary to maintain protection. Vaccines prepared from living avirulent strains may confer satisfactory immunity for approximately 6 months after a basic series of two injections. Reimmunization is accomplished every 6 months.

j. Treatment. Prompt treatment is essential and usually effective. Antibiotic choice will vary with the type of infection, clinical appearance of the patient, and geographical area.

k. Epidemicity. Bubonic plague is not directly communicable from man to man; however, pneumonic plague is intensely communicable during the acute period. Strict area quarantine and sanitation, in addition to other measures such as rat control and rat flea extermination, are essential to control outbreaks. Flea control must precede rodent control.

l. Stability. The organism may remain viable in water for 2 to 30 days and in moist meal and grain for about 2 weeks. At near freezing temperatures, it will remain alive from months to years, but is killed by exposure to heat at 130° F. for 15 minutes. It remains viable for some time in dry sputum, flea feces, and buried bodies; however, it is killed by exposure to sunlight for 3 to 5 hours. Decontamination can be effected by boiling, dry heat above 130° F., steam, or treatment with lysol or chloride of lime.

29. *Vibrio Comma* (Cholera)

a. Description. *Vibrio comma* is a short, slightly bent, motile, gram-negative, nonsporulating rod which releases a powerful endotoxin upon disintegration.

b. Disease Produced. Cholera is an acute in-

fectious gastrointestinal disease of man characterized by sudden onset with nausea, vomiting, profuse watery diarrhea with "rice-water" appearance, rapid loss of body fluids, toxemia, and collapse.

c. Sources of Infection. Feces and vomitus of patients, feces of persons in incubation periods or of convalescents, and temporary carriers are sources of infection.

d. Modes of Transmission. Transmission is through direct or indirect fecal contamination of water or foods, by soiled hands or utensils, or by flies as mechanical vectors.

e. Incubation Period. The incubation period is from 1 to 5 days, usually 3 days.

f. Susceptibility and Resistance. All populations are susceptible; however, poorly nourished people are most susceptible. Recovery from an attack is followed by an immunity which may furnish some protection for not more than 6 months.

g. Prevalence. Endemic centers exist in India and southeastern Asia, China, Japan, and the Philippines from which the disease may spread along human communication lines to remote countries and cause epidemics. It is normally absent from the Western Hemisphere and Europe.

h. Mortality. The mortality rate ranges from about 15 to 90 percent in untreated cases but can be reduced to 5 percent in treated cases.

i. Immunization. Immunization with vaccines is of variable effectiveness and uncertain duration; booster inoculations are required at 6-month intervals. Recovery from the disease may result in immunity which can last for many years.

j. Treatment. The first consideration in the treatment of cholera is to replenish fluid and electrolyte losses of the body. Tetracycline therapy appears to enhance the effectiveness of rehydration by reducing the volume and duration of diarrhea and aiding the disappearance of the organisms.

k. Epidemicity. Epidemicity is very high under unsanitary conditions involving water supplies, foods, feces, and fly control.

l. Stability. The organism is easily killed by drying. It will not remain viable in pure water but will survive up to 24 hours in sewage and as long as 6 weeks in certain types of relatively impure water containing salts and organic matter.

It can withstand freezing for 3 to 4 days. It is readily killed by dry heat at 212° F., by steam, boiling, short exposure to ordinary disinfectants, and by chlorination of water.

30. *Corynebacterium Diphtheriae* (Diphtheria)

a. Description. This bacterium (a slender, often slightly curved rod) is gram-positive, nonmotile, non-sporulating, and nonacid fast. It varies from 2 to 7 microns in length and from 0.5 to 1 micron in diameter. The rodlike forms usually are arranged in palisades and often exhibit club-shaped terminal swellings. They stain irregularly, displaying bars or granules as a result of irregular distribution of protoplasm within the cell. Although the organism is normally aerobic, it is often capable of anaerobic cultivation. It produces a highly potent exotoxin, both in the body and in culture.

b. Disease Produced. Diphtheria is an acute febrile disease generally characterized by local infection, usually involving the respiratory passages. The systemic manifestations are due to absorption of the soluble exotoxin into the bloodstream. The bacteria multiply rapidly in the tonsils, nose, and throat where thick fibrinous membranes appear on the surfaces of the mucous membranes, causing sore throat and stoppage of air passages. Skin and wound infections are not uncommon in tropical and subtropical climates. Early diphtheria is usually a surprisingly mild disease unless symptoms of obstruction develop. During the first few days of infection, the throat is not particularly sore, there is only slight fever, and there are no severe symptoms. This lack of obvious symptoms is characteristic of diphtheria in the adult; and it is especially dangerous when infection occurs in the nasal passages because the infection is not recognized, and treatment is not begun until sufficient exotoxin has been absorbed to cause damage to other parts of the body including the heart, kidneys, and central nervous system.

c. Sources of Infection. Discharges from the nose or throat of infected persons and of healthy carriers and from lesions are sources of infection.

d. Modes of Transmission. The infection is contracted by direct contact with patients or carriers, by droplet infection, or through articles freshly contaminated with nose and throat discharges of infected individuals.

e. Incubation Period. The incubation period is usually from 2 to 5 days but occasionally may be longer.

f. Susceptibility and Resistance. Susceptibility is general in the absence of previous contact with the organism or its toxin. In the past, there was a very high percentage of immunity in the adult population because of repeated contact with usually unrecognized sources of infection. The current, widespread practice of diphtheria vaccination during infancy affords less frequent opportunity for natural exposure to doses sufficient to produce immunity. Therefore, the adult population is now more susceptible to the disease than in the past. This susceptibility can be accurately measured by means of the Schick test. Recovery from the disease usually results in a persisting immunity.

g. Prevalence. The disease is endemic and epidemic around the world. It is more common in temperate zones during the fall and winter. Age distribution of cases and death rate depends largely upon childhood immunization practices.

h. Mortality. The mortality rate is variable, depending upon the site of the infection; among untreated cases, it may range from 10 to 12 percent. In cases receiving antitoxin, the rate is lowered to 2 to 5 percent.

i. Immunization. Diphtheria toxoid is extremely effective. Permanent immunity may be maintained by means of booster inoculations at regular intervals.

j. Treatment. Diphtheria antitoxin is effective when given in adequate dosage promptly upon appearance of symptoms. Penicillin, a supplementary treatment, suppresses secondary invaders, shortens the period of illness, and reduces the number of convalescent carriers.

k. Epidemicity. Epidemicity may be high, depending on the immunity status of the population and the degree of exposure to the disease. A large proportion of the cases occurs in children under 5 years of age.

l. Stability. The diphtheria organism is more resistant to light, drying, and freezing than are most nonsporulating bacilli. It remains viable for a long time in air and dust. It is capable of surviving for many hours on a cotton swab and has been cultured from dried bits of diphtheritic pseudomembrane after 14 weeks. It is destroyed

by ordinary antiseptics, boiling for 1 minute, or by heat at 136° F. for 10 minutes.

31. *Salmonella Typhosa* (Typhoid Fever)

a. Description. This organism is a rod-shaped, motile, nonsporulating, gram-negative bacterium. It is also known as *S. typhi*.

b. Disease Produced. Typhoid fever is a systemic infection characterized by prolonged fever, lymphoid tissue involvement, ulceration of the intestines, enlargement of the spleen, rose-colored spots on the skin, and constipation or diarrhea.

c. Sources of Infection. Feces and urine of infected patients and of carriers are sources of infection.

d. Modes of Transmission. Transmission is through the alimentary tract by indirect contact with a typhoid patient or a chronic carrier; by consumption of contaminated water, food, milk, or shellfish; and by flies as mechanical vectors. Spread by direct contact is rare.

e. Incubation Period. The incubation period is from 6 to 21 days, usually 10 to 14 days.

f. Susceptibility and Resistance. Susceptibility is general, although some adults have a natural active acquired immunity from unrecognized infection. Recovery is usually followed by a high level of resistance.

g. Prevalence. The disease is widespread throughout the world. Once endemic and epidemic in most large cities of North America, the disease

incidence has been steadily decreasing particularly in areas supplied with safe water and pasteurized milk and where modern sewage disposal facilities are used. It is still found in some rural areas of the United States, usually as sporadic cases or in small carrier or contact epidemics. It is most common in the Middle and Far East, Africa, Eastern Europe, Central America, and South America.

h. Mortality. The mortality rate in untreated cases ranges from 7 to 14 percent; treatment reduces this rate to about 2 percent.

i. Immunization. Inoculation with typhoid vaccine produces an artificial active immunity of about 2 years' duration. High protection can be maintained by a booster injection of vaccine each 3 years thereafter.

j. Treatment. Prompt use of appropriate antibiotics (chloramphenicol or aureomycin) shortens the period of communicability and rapidly cures the disease.

k. Epidemicity. Epidemicity is high in the presence of carriers or diseased persons and in the absence of sanitary control of water, food, and milk supplies and where individuals are not protected by immunization.

l. Stability. The organism remains viable for 2 to 3 weeks in water, up to 3 months in ice and snow, and for 1 to 2 months in fecal material. Pasteurization, exposure to heat at 132° F. for 20 minutes, exposure to 5 percent phenol or 1:500 bichloride of mercury for 5 minutes, cooking, and boiling are effective decontamination measures.

Section IV. RICKETTSIAE

32. *Rickettsia prowazeki* (Epidemic Typhus)

a. Description. *Rickettsia prowazeki* is a non-motile, minute, coccoid or rod-shaped rickettsia, occurring sometimes in pairs or chains, with a diameter of about 0.3 micron. It occurs in a variety of sizes and shapes.

b. Disease Produced. The disease is known as classic epidemic (human or louse-borne) typhus. It is an acute, infectious disease of man and is characterized by severe headache, sustained high fever, general pains, and a skin rash.

c. Source of Infection. Persons harboring the infection or manifesting the disease are sources of infection.

d. Modes of Transmission. Transmission is

mainly by body lice which have fed upon infected persons. The individual usually becomes infected by scratching or rubbing louse feces into a wound made by the louse bite, by crushing an infected louse on the skin, or by rubbing louse feces into the eyes. It is possible that the rickettsia in louse feces on dirty clothing may be transmitted through the air to the respiratory tract.

e. Incubation Period. The incubation period is usually from 6 to 15 days, but may be shorter if the infecting dose is large.

f. Susceptibility and Resistance. All people are susceptible. One attack confers immunity which is not always permanent.

g. Prevalence. The disease is widely distributed

in people living under crowded and unsanitary conditions, particularly in Europe and Asia. Cases occur throughout the year with an increase during the cold months.

h. Mortality. The mortality rate is from 10 to 40 percent, varying in different epidemics and with the age of individuals.

i. Immunization. Vaccines confer considerable protection of uncertain duration; immunization should be repeated every 4 months where danger of typhus is present. The vaccine reduces risk of infection, modifies the course of the disease, and lowers the mortality rate.

j. Treatment. The course of the disease can be shortened by use of antibiotics (tetracyclines and chloramphenicol). Supportive treatment and prevention of secondary infections are essential.

k. Epidemicity. The disease is not contagious nor communicable directly from man to man. Epidemics usually occur in winter under crowded and unsanitary conditions, particularly during famine and war, and when the population is heavily infected with body lice. Louse eradication is used to control epidemics.

l. Stability. The organism is destroyed by heat at 112° F. for 15 to 30 minutes and inactivated by use of 0.1 percent formalin and 0.5 percent phenol.

33. *Rickettsia Mooseri* (Endemic Typhus)

a. Description. This rickettsia is similar to *Rickettsia prowazeki* (para 32), but with less variation in appearance.

b. Disease Produced. Endemic (murine, rat, or flea-borne) typhus is similar to classic epidemic typhus except that the disease is milder and has a somewhat slower onset.

c. Sources of Infection. Infected rodents, particularly rats, are sources of infection.

d. Mode of Transmission. The disease is transmitted from rodents to man by the bite of the rat flea.

e. Incubation Period. The incubation period ranges from 6 to 14 days and is commonly 12 days.

f. Susceptibility and Resistance. Susceptibility is general. One attack usually confers a high degree of immunity.

g. Prevalence. The disease is widely distributed in temperate, subtropical, and tropical countries.

It is transmissible to man throughout the year with an increase in summer and fall.

h. Mortality. The mortality rate is about 2 percent, increasing in older people (over 50 years of age).

i. Immunization. Investigations on vaccines have been discontinued because of the effectiveness of modern insecticides and therapy.

j. Treatment. Treatment is similar to that for classic epidemic typhus (para 32). Delayed recognition of the disease may result in the optimum period for treatment being passed.

k. Epidemicity. The disease is not contagious. Rodent and flea eradication are the most successful control measures.

l. Stability. Stability is the same as for *Rickettsia prowazeki* (para 32).

34. *Rickettsia Rickettsii* (Rocky Mountain Spotted Fever)

a. Description. This rickettsia is a diplococcus-like microorganism with the distal ends tapered so that the pairs resemble minute pneumococci. The average microorganism is 1 micron in length and 0.2 to 0.3 micron in width.

b. Disease Produced. Rocky Mountain spotted fever (Sao Paulo fever in South America) is an acute infectious disease characterized by fever and joint and muscular pains. A skin rash that rapidly spreads from the ankles and wrists to the legs, arms, and chest usually appears on the third or fourth day. The infected person often has a distinct aversion to light (photophobia).

c. Sources of Infection. In the United States, infected ticks, such as the common dog tick in the east and south, the wood or sheep tick in the northwest, and occasionally the lone star tick in the southwest, are sources of infection. In other countries, the vectors may be various other species of ticks. The infection is passed from generation to generation in ticks and is probably maintained through the winter by larvae feeding on susceptible wild rodents.

d. Modes of Transmission. The disease is transmitted to man by the bite of an infected tick or by contamination of abraded skin with infected tick tissues or feces. It can be transmitted in the air, although transmission in this manner is not normally encountered.

e. Incubation Period. The incubation period is from 3 to 10 days.

f. Susceptibility and Resistance. Susceptibility is probably general; recovery from an attack is followed by varying degrees of immunity.

g. Prevalence. The disease occurs throughout North America and in some parts of South America. Occurrence is usually in spring and early summer when adult ticks appear.

h. Mortality. The mortality rate is about 30 percent in untreated cases (higher in adults); however, death is uncommon when specific therapy is given.

i. Immunization. An effective egg-yolk vaccine that lessens the chance of infection and lowers the mortality rate is available. Yearly booster doses are needed to attain maximum protection.

j. Treatment. Appropriate antibiotics (chlorotetracycline, chloramphenicol, and oxytetracycline) are effective in reducing the mortality rate and in shortening the course of the disease. Supportive treatment is also indicated.

k. Epidemicity. The disease is not communicable from man to man. Tick eradication and preventive immunization are the best control measures.

l. Stability. *Rickettsia rickettsii* can be killed by exposure to a temperature of 112° F. for 10 minutes and by drying for 10 hours. It is inactivated by 0.1 percent formalin or 0.5 percent phenol.

35. *Coxiella Burneti* (Q Fever)

a. Description. This rickettsia is a bacterium-like organism which may vary in size and shape from a tapered rod 0.25 by 0.5 micron to a diplobacillus 0.25 by 1.5 microns.

b. Disease Produced. Q fever, also known as nine mile fever and North Queensland fever, is an influenzalike disease that is moderately incapacitating and is characterized by the sudden onset of acute fever, headache, chills, weakness, and profuse perspiration. Pulmonary involvement occurs in the majority of cases and is accompanied by mild cough, scanty expectoration, and chest

pains. Q fever is distinguished from other rickettsial diseases by its failure to cause a skin rash.

c. Sources of Infection. Cows, sheep, goats, and wild animals appear to be natural reservoirs, with many types of ticks transmitting the disease among them. The organism may be found in the milk and mammary glands of infected cows, in the milk of sheep and goats, and in dust-laden air from dairy cattle barns and goat pens that harbor infected animals.

d. Modes of Transmission. In man, the disease appears to be transmitted by inhalation of dust contaminated with material (feces or tissues) from infected animals. Raw milk from cows and goats, dried milk, raw wool, hides, infected meat, goat hair, and tick feces, as well as cultures of infected tissues, have been involved in establishing infections.

e. Incubation Period. The incubation period is from 2 to 3 weeks.

f. Susceptibility and Resistance. Susceptibility is general. Recovery from an attack confers immunity for at least 1 year.

g. Prevalence. This disease is endemic in the United States, particularly in California. It has also been reported in Australia, the Mediterranean area, western Europe, the Near East, the Balkans, Spain, England, Panama, and scattered areas of Africa.

h. Mortality. The mortality rate is less than 1 percent of the infected individuals.

i. Immunization. Vaccines have been effective when used by laboratory personnel, slaughterhouse employees, and stockyard workers.

j. Treatment. Tetracycline antibiotics are generally effective. Supportive treatment is indicated.

k. Epidemicity. The disease is relatively non-contagious. Outbreaks have occurred among slaughterhouse and stockyard workers in the United States.

l. Stability. The microorganism is resistant to temperature changes from 72° F to -94° F.

Section V VIRUSES

36. Encephalitis and Encephalomyelitis Viruses

a. Description. These viruses are small neurotropic organisms. They are distinguishable anti-

genically, but some are so closely related that they appear to be variants of a common ancestor.

b. Diseases Produced. There are several types of encephalitic diseases; each is produced by a spe-

cific virus. Their clinical manifestations are similar; they vary mainly in severity and the rate of progress of symptoms. They are characterized by inflammation of the meninges of the brain, headache, fever, dizziness, drowsiness or stupor, tremors or convulsions, severe prostration, occasional paralysis, and muscular incoordination. The diseases are usually acute, prostrating, and of short duration. The following are some of the more common types.

(1) St Louis encephalitis is endemic and epidemic in the central and western United States where it occurs in the summer and fall when arthropod vectors are most numerous.

(2) Eastern equine encephalomyelitis and Western equine encephalomyelitis occur, usually in the summer, in Canada, the United States, Central America, and South America. They are viral diseases of certain wild birds, such as egrets, swans, pheasants, and grackles; they are transmissible to man, horses, and mules. Mosquitoes may carry the virus between these animals and man.

(3) Venezuelan equine encephalomyelitis occurs in Central America and South America. Birds are the most common reservoirs of the virus in nature but do not show evidence of the disease. When the disease is transmitted to man, it usually induces a mild disease with varied symptoms.

(4) Japanese B-type encephalitis occurs in Japan, Korea, China, and some Pacific islands.

(5) Russian spring-summer encephalitis is endemic to the Far East provinces of Russia and it occurs less frequently in European and Siberian Russia.

c. Sources of Infection. Wild birds are the principal sources of infection for the virus types occurring in the United States.

d. Modes of Transmission. Mosquitoes transmit all types of the disease except the Russian spring-summer type, which is tickborne.

e. Incubation Period. The incubation period is usually from 4 to 15 days but may be as long as 24 days.

f. Susceptibility and Resistance. Susceptibility ranges from 90 to 100 percent. Recovery from an infection results in an excellent short-term immunity to the specific virus but not to any other type.

g. Prevalence. The diseases are usually prevalent in summer and early fall; they are usually

limited to areas and years of sustained high temperature and large numbers of mosquitoes. Highest rates are in rural and suburban localities.

h. Mortality. Venezuelan equine encephalomyelitis has a mortality rate of about 1 percent. Information available indicates the average for the other types is from 5 to 60 percent. The Japanese B-type encephalitis and Eastern equine encephalomyelitis produce the highest percentage of fatalities.

i. Immunization. Some effective virus vaccines have been developed on a small scale, but widespread use is not practiced at present.

j. Treatment. Treatment is supportive only; no specific therapy exists. Antibiotics have not been effective in the treatment of the encephalitides.

k. Epidemicity. The disease is irregularly epidemic in dry farming areas of the midwestern, southwestern, and eastern United States and endemic in many hot, irrigated western United States valley areas. Transmission from man to man is not known to occur. Transmission of encephalomyelitis virus by inhalation has occurred accidentally in laboratories.

l. Stability. Stability varies among the different types. All may be preserved frozen at -94°F . St Louis and Japanese B viruses are inactivated at 133°F in 30 minutes; Russian spring-summer virus is inactivated at 140°F in 10 minutes; but the Western and Eastern equine viruses withstand this treatment and also resist 0.2 percent chloroform, 1 or 2 percent phenol, and 0.05 percent mercuric chloride. St Louis and Russian viruses are inactivated by 1 percent formalin within 1 day. The Russian virus is inactivated by 1 percent phenol in 10 days, but the St Louis virus resists this treatment for at least 25 days.

37. Variola Virus (Smallpox)

a. Description. This virus ranges from 0.15 to 0.2 micron in size and can pass through most filters.

b. Disease Produced. Smallpox, or variola, is a highly contagious disease characterized by severe fever and small blisters of the skin. The blisters later contain pus and form crusts which fall off in 10 to 40 days after the first lesions have appeared, leaving pink scars that gradually fade. Complications of the disease include secondary bacterial infections.

c. Sources of Infection. Respiratory discharges

from patients with lesions of the mucous membranes and skin of infected persons are sources of infection.

d. Modes of Transmission. Transmission is through contact with patients having the disease or with articles or persons freshly contaminated by discharges from the lesions of infected individuals.

e. Incubation Period. The incubation period is from 7 to 16 days, commonly 9 to 12 days.

f. Susceptibility and Resistance. The disease is highly communicable and contagious. Susceptibility is universal except in vaccinated persons. Recovery usually is followed by permanent immunity.

g. Prevalence. Prevalence is worldwide except in immunized or nonexposed populations. The frequency is greatest in winter and least in summer.

h. Mortality. The mortality rate ranges from 1 percent with the mild type of the disease to 30 to 35 percent with the more severe types.

i. Immunization. Artificial immunity by vaccination may be completely effective for 2 to 20 years, but revaccination every 3 years is advisable to maintain a high degree of immunity. A high degree of immunity is required against severe strains or high numbers of the virus.

j. Treatment. No specific therapy is available. Treatment is aimed at making the patient comfortable and preventing complications.

k. Epidemicity. Epidemicity is high, depending on immunity status of the population and exposure to the disease.

l. Stability. The virus is viable in water for several years at 39° to 48° F. It is resistant in dry or wet form to very low temperatures; it is more resistant in the dry state than in the wet state. Decontamination can be accomplished by exposure of the organism to alcohol and acetone for 1 hour at room temperature, but the virus is resistant to some other disinfectants. Moist heat above 140° F. and dry heat above 212° F. are effective in 10 minutes.

38. Yellow Fever Virus

a. Description. The virus particles are estimated to range from 0.017 to 0.028 micron in size and can pass through most filters.

b. Disease Produced. Yellow fever (classic urban form) is characterized by sudden onset, chills, fever, prostration, headache, backache, muscular pain, congestion of mucous membranes, severe gastrointestinal disturbances, and jaundice (yellowing of the skin) from liver damage. Hemorrhage from the stomach and gums often occurs. The disease is of short duration; either death or complete recovery occurs within 2 weeks of onset. A forest form in South America and Africa is known as jungle yellow fever; it appears to be clinically identical to the classic type.

c. Source of Infection. The blood from humans or monkeys infected with yellow fever is the source of infection.

d. Modes of Transmission. Transmission is ordinarily by the bite of the female *Aedes aegypti* mosquito; however, in the forests of South America and Africa, transmission is usually by some other mosquitoes, such as *A. simpsoni* and *Hoemagogus* species.

e. Incubation Period. The incubation period is from 3 to 6 days, rarely longer.

f. Susceptibility and Resistance. Susceptibility is general. Recovery from an attack is followed by lasting immunity. Infants born to immune mothers are immune up to 6 months. Persons in endemic areas may have nonapparent infections.

g. Prevalence. The disease is endemic in man, monkeys, and some other mammals in Western and Central Africa, and in certain monkeys in the tropical forests of Central and South America. Occasional human cases and epidemics occur in these areas and neighboring urban or rural localities. The disease is unknown in the Orient.

h. Mortality. The mortality rate among the native populations of endemic regions is usually less than 5 percent. In areas where the disease is not endemic, a mortality rate of 30 to 40 percent is not uncommon.

i. Immunization. Inoculation with a modified living virus vaccine confers an active immunity that lasts for a minimum of 2 years and probably longer.

j. Treatment. There is no specific treatment. Supportive treatment (bed rest and fluids) is essential for even the mildest cases.

k. Epidemicity. Occasional epidemics occur in Africa, Central America, and South America. These epidemics can be lessened by mosquito control and active immunization.

l. Stability. The virus is resistant to freezing and drying but is destroyed by heat at 140° F. or above for 10 minutes. It is easily inactivated by common antiseptics.

39. Rift Valley Fever Virus

a. Description. This virus is 0.023 to 0.035 micron in size and will pass through most filters.

b. Disease Produced. The disease is severe but seldom fatal in man. The affected individual experiences fever, severe headache, muscular and joint pain, and dizziness.

c. Sources of Infection. Infected animals are the sources of infection.

d. Modes of Transmission. The reservoir of infection is jungle animals, cattle, sheep, and goats. Man acquires the disease by direct contact with the tissues of infected animals, the bite of mosquitoes, and in all probability, by inhalation of the virus.

e. Incubation Period. The incubation period is normally 4 to 6 days.

f. Susceptibility and Resistance. Sheep are highly susceptible; goats, cattle, and man are less susceptible. Mice, rats, cats, and apes are reported to be susceptible; horses, rabbits, guinea pigs, and birds seem to be immune. Humans and animals that recover from the disease are immune.

g. Prevalence. The disease is found in Africa, particularly in Kenya.

h. Mortality. The mortality rate is 90 to 95 percent in lambs, 20 to 25 percent in adult sheep, and about 10 percent in cattle. The mortality rate is less than 1 percent in man.

i. Immunization. A living virus vaccine is used effectively in pregnant sheep to insure that the lambs are immune during their period of greatest risk. A formalin-inactivated vaccine is being tested for use in man.

j. Treatment. Treatment is supportive only. No specific treatment is available.

k. Epidemicity. The disease is fairly widespread in Central Africa and South Africa. Epidemicity is dependent on the presence of infected animals, susceptible animals, and the mosquitoes that are capable of transmitting the disease. Although man can presumably be infected by arthropods, many human infections occur as a result of handling infected animal tissue and are thus

common in farmers, veterinarians, butchers, and laboratory workers.

l. Stability. The virus is destroyed by exposure to a temperature of 132° F. for 40 minutes. It may be preserved for long periods by lyophilization (freeze-drying).

40. Rabies Virus

a. Description. The diameter of the rabies virus has been estimated to be from 0.1 to 0.15 micron. The rabies virus is not readily filterable; it will pass through diatomaceous earth and unglazed porcelain filters.

b. Disease Produced. The early characteristics of rabies include fever, headache, malaise, anorexia, nausea, and sore throat. The onset of the excitement stage is gradual and is marked by increasing nervousness, insomnia, anxiety, and apprehension. The outstanding clinical symptom is related to the act of swallowing; when fluid comes in contact with the fauces, it is expelled with considerable force and painful, spasmodic contractions of the throat and respiratory muscles take place. Convulsive seizures are common. Maniacal mannerisms, such as tearing of clothing and breaking of objects, are not uncommon; but viciousness, such as fighting, is rare. In the majority of cases involving rabies, the patient dies in the acute excitement stage of the disease during a convulsion.

c. Sources of Infection. Animals infected with rabies are the sources of infection.

d. Modes of Transmission. Rabies is contracted from the bites of rabid animals or from the inhalation of the viral organism.

e. Incubation Period. Depending on the site of the bite, the incubation period can range from 10 days to 8 months, but is normally 50 to 60 days.

f. Susceptibility and Resistance. All warm-blooded mammals are susceptible to rabies. Once clinical symptoms develop, there are no survivors, with the exception of the bat. Natural immunity in man is unknown.

g. Prevalence. Prevalence is virtually worldwide with the exception of isolated areas, such as England and Hawaii.

h. Mortality. The mortality rate is 100 percent, with the exception of the bat.

i. Immunization. Both preexposure and post-exposure vaccines have been developed.

j. Treatment. There is no specific treatment; supportive treatment is essential.

k. Epidemicity. Man is considered the end host for rabies; therefore, transmission from man to man does not normally occur. Dogs are considered to be potentially the most dangerous source, and cats are considered the second most likely source of rabies. Wild mammals serve as a large and uncontrollable reservoir and pose a constant threat to man and animals.

l. Stability. The virus, when stored in undiluted glycerol, retains its infectivity for several weeks at room temperature. The virus is resistant to phenol and may remain infective for several months in 0.5 percent phenol. The virus is rapidly destroyed by sunlight or by ultraviolet light. It is readily destroyed by bichloride of mercury and strong acids and bases.

41. Dengue Fever Virus

a. Description. This virus is very small, about 0.011 to 0.025 micron in size.

b. Disease Produced. Dengue fever is an acute, extremely disabling disease usually of sudden onset characterized by fever, chills, intense headache, backache, pain behind the eyes, joint and muscle pains, weakness and prostration, and irregular rash. The fever rarely exceeds 105° F.; it lasts for 5 or 6 days and usually terminates abruptly after reaching a peak. Loss of appetite and constipation are common during the entire illness; abdominal discomfort with colicky pains and tenderness may be manifested. The acute phase lasts only about a week, but convalescence may take several weeks. Dengue fever is said to be temporarily the most incapacitating, although the least fatal, of the contagious diseases.

c. Sources of Infection. Sources of infection are the blood of infected persons 1 day before and up to 5 days following onset of symptoms; infected mosquitoes; and, in some regions, possibly the blood of infected monkeys.

d. Mode of Transmission. The disease is transmitted by the bite of the *Aedes aegypti* mosquito and certain other species of *Aedes* mosquitoes that have become infected by biting an infected individual.

e. Incubation Period. The incubation period is from 4 to 10 days, most often 5 to 8 days.

f. Susceptibility and Resistance. All persons except natives of endemic areas appear to be fully susceptible. Immunity to the invading strain is apparently permanent after recovery, but reinfection with a different strain is possible. However, if reinfection occurs within a few months of the primary infection, the disease is much milder because of cross immunity.

g. Prevalence. The disease is found mainly in the tropics and subtropics; it extends to the Gulf Coast of the United States. It may occur wherever the vector mosquitoes exist.

h. Mortality. The mortality rate is very low and approaches zero percent.

i. Immunization. A mouse-adapted virus vaccine has been developed and may be useful in control of epidemics and for troops going to areas where dengue fever is endemic.

j. Treatment. There is no specific therapy; supportive treatment is essential.

k. Epidemicity. The virus does not spread directly from man to man. Epidemics occur in areas where the vector mosquitoes are present in large numbers. The infectivity rate is extraordinarily high; 75 to 100 percent of the inhabitants of a locality may be affected. Spread of the disease can be prevented by diligent mosquito control measures.

l. Stability. Blood from a patient remains infectious after storage in a refrigerator for several weeks. Mosquitoes do not transmit the infection through their eggs to the young; however, the infected insects probably remain so for life. The virus is inactivated by ultraviolet light and by 0.5 percent formalin.

Section VI. FUNGI

42. *Coccidioides Immitis*

a. Description. In man and animals, this fungus occurs as thick-walled, endospore-filled spherules 20 to 80 microns in diameter. In artificial culture, it appears as a fluffy, white, cottony mold.

b. Disease Produced. *Coccidioidomycosis* is a highly infectious disease. The usual primary form (known as valley or San Joaquin fever) is an acute, disabling, self-limiting, respiratory infection resembling influenza. It is usually associated

with a low-grade fever, rarely exceeding 101° F., and a slight, nonproductive cough. The secondary, progressive form (known as coccidioidal granuloma) is a chronic, malignant, disseminated infection that involves any and all organs of the body, including the skin and bones, and produces numerous abscesses. The progressive form is often fatal. A primary, localized form of infection may occur on the exposed surfaces of the skin; it sometimes develops into the progressive, disseminated form of infection.

c. Sources of Infection. Dust, soil, and vegetation contaminated with spores of this fungus are sources of infection.

d. Modes of Transmission. Transmission occurs by inhalation of spores in dust from soils and dry vegetation and possibly through skin scratches or wounds.

e. Incubation Period. The incubation period for the primary pulmonary form is 10 to 21 days, the average being about 12 days. The clinically active cases in about 1 percent of whites, and a much higher percentage (12 to 20 percent) of dark-skinned peoples, develop into the progressive form of the disease, usually within a period of weeks or months after onset of the primary infection. The progressive form is not necessarily preceded by symptoms of the primary infection.

f. Susceptibility and Resistance. Susceptibility to the primary infection is general. With the progressive form of the disease, dark-skinned peoples appear to be much more susceptible than whites; and females are less apt to develop granulomatous lesions than males. Probably up to 60 percent of infected persons have no symptoms but do develop immunity.

g. Prevalence. Recognized endemic areas are the arid southwestern United States, northern Mexico, central Argentina, Russia, and other areas having similar climates and terrain.

h. Mortality. The mortality rate is about 50 percent in the secondary, progressive form; the rate in the pulmonary form is unknown (although low) due to many nonapparent infections.

i. Immunization. Vaccine therapy is only in the experimental stage of development; present prospects for a good vaccine are poor.

j. Treatment. Supportive treatment with complete rest is the standard procedure. Localized lesions may be treated by X-ray or surgery. Prognosis is excellent in the primary pulmonary in-

fection, good in the primary cutaneous type, and very poor in the progressive disseminated form of the disease.

k. Epidemicity. The disease is noncontagious. Small epidemics may occur in hot, dry seasons among groups, such as troops stationed in endemic areas or engaged in maneuvers in such areas. In areas of endemic infection, dust control (such as paving roads and runways, oiling athletic fields, and planting lawns) is effective in reducing the exposure rate and the number of infections.

l. Stability. Spores of this fungus are highly resistant to drying and will live for months in culture or in suitable soil (dust). They are destroyed by autoclaving for 15 minutes or by exposure to formaldehyde fumes for 48 hours. It is not believed that soil contamination would be a problem except, perhaps, in the few areas of the world where the disease is already endemic. However, decontamination of large areas, even if possible, would not appear to be practicable.

43. *Histoplasma Capsulatum* (Histoplasmosis)

a. Description. This fungus appears as small (1 to 5 microns), oval, yeastlike, intracellular bodies in the tissues of man and animals and in culture on sealed blood agar slants at 96° to 98° F. In culture at room temperature, it forms a white, cottony, moldlike growth.

b. Disease Produced. Histoplasmosis is a chronic, local or systemic, infectious disease of man and animals. It is characterized by low grade granulomatous lesions of the skin or mucous membranes and/or tuberculosis-like lesions of the lungs, and by involvement of internal organs, especially the spleen and liver.

c. Sources of Infection. Dust contaminated with spores of this fungus is a source of infection. The fungus has been recovered from man, dogs, cats, rodents, skunks, opossums, soil, and air.

d. Modes of Transmission. Transmission is usually by inhalation of spores in dust from soils and dried organic matter; it may also be by ingestion or by entry through skin scratches.

e. Incubation Period. In the few reported epidemics, symptoms appeared within 5 to 18 days following exposure.

f. Susceptibility and Resistance. Susceptibility is general. The occurrence and severity of clinical symptoms depend upon the dosage of the infec-

tious fungus. The extreme infectiousness of the disease is shown by a positive histoplasmin skin test in 80 percent or more of the adult population in local endemic areas. The effect of dosage is illustrated by essentially 100 percent epidemic involvement among groups exposed to highly contaminated dust in enclosed places.

g. Prevalence. The disease has been reported from widely scattered areas in North, Central and South America; Europe; Africa; Hawaii; Indonesia; Japan; and the Philippines. It is par-

ticularly prevalent in the eastern and central United States.

h. Mortality. The progressive form is usually fatal; however, less than 1 percent of the naturally occurring primary infections develop into the progressive form.

i. Immunization. Immunization has not been developed.

j. Treatment. Supportive treatment is used. Although there are several promising drugs, no treatment has been found that is uniformly effective against the disease.

Table 1. Potential Biological Antipersonnel Agents

Microorganism	Mode of transmission ¹	Incubation period ² (days)	Mortality rate ³ (percent)	Vaccine ⁴	Treatment ⁴
Bacteria					
<i>Bacillus anthracis</i> (anthrax)	A, D, I	1-7	5-100 ⁵	+	E ⁶
<i>Brucella</i> group (brucellosis)	A, D, I	5-21	2-6	+	E
<i>Francisella tularensis</i> (tularemia)	A, D, I, V	1-10	<30	++	E
<i>Pasteurella pestis</i> (plague)	A, V	2-6	25-100 ⁷	+++	E ⁶
<i>Vibrio comma</i> (cholera)	I	1-5	15-90	+++	E
<i>Corynebacterium diphtheriae</i> (diphtheria)	A, D	2-5	5-12	+++	E
<i>Salmonella typhosa</i> (typhoid fever)	I	6-21	7-14	+++	E
Rickettsiae					
<i>Rickettsia prowazekii</i> (epidemic or louse-borne typhus)	V	6-15	10-40	+++	E
<i>Rickettsia mooseri</i> (endemic or flea-borne typhus)	V	6-14	2-5	-	E
<i>Rickettsia rickettsii</i> (Rocky Mountain spotted fever)	V	3-10	30 (approx)	-	E
<i>Coxiella burnetii</i> (Q fever)	A, I	14-21	<1	++	E
Viruses					
Group A Arboviruses					
Eastern equine encephalitis (EEE)	V ⁸	4-24	60 (approx)	-	N
Venezuelan equine encephalitis (VEE)	V ⁸	4-24	<1	++	N
Group B Arboviruses					
St Louis encephalitis	V (mosquito)	4-24		-	N
Japanese B encephalitis	V (mosquito)	5-15	10-80	++	N
Russian spring-summer encephalitis (RSSE)	V (tick)	7-14	3-40	+	N
Yellow fever	V (mosquito)	3-6	5-40	+++	N
Dengue fever	V (mosquito)	4-10	<1	+	N
Ungrouped Arbovirus					
Rift Valley fever	V (mosquito)	4-6	<1	-	N
Poxvirus					
Variola virus (smallpox)	A, D	7-16	1-35	+++	N
Myxovirus					
Rabies virus	A, D ⁹	6-365	100	++	E
Fungi					
<i>Coccidioides immitis</i> (coccidioidomycosis)	A, D	10-21	1-50	-	E
<i>Histoplasma capsulatum</i> (histoplasmosis)	A	5-18		-	E

¹ Transmission can be by aerosol—A, direct contact—D, ingestion—I, and vector—V.

² Incubation periods and mortality rates vary according to a number of factors (e.g., ability of the host to resist infection, infective dose, portal of entry, and virulence of the microorganism).

³ + Indicates vaccine available but of questionable value; ++ indicates vaccine available but mainly used in high risk individuals; +++ indicates vaccine used extensively; - indicates no vaccine available.

⁴ E indicates effective treatment available; N indicates no specific treatment.

⁵ The 5 percent represents mortality due to skin form; 100 percent represents mortality due to respiratory form.

⁶ Treatment must be initiated in the earliest stage of the pulmonary form to be effective.

⁷ The 25 percent represents mortality due to bubonic form; 100 percent represents mortality due to pneumonic form.

⁸ Mosquitoes are thought to be the primary vectors, but this has not been proved.

⁹ Direct contact refers to being bitten by a rabid animal, which is the usual means of transmission, or coming into contact with a rabid animal.

k. Epidemicity. The disease is noncontagious.

l. Stability. Spores are viable for several months (probably years) in dry soil and for a

period of months in tap water at temperatures ranging from near freezing to 98° F. They are destroyed by heat at 131° F. for 15 minutes and 1 to 2 percent formalin in 24 hours.

CHAPTER 5

POTENTIAL BIOLOGICAL ANTIANIMAL AGENTS

Section I. INTRODUCTION

44. General

Biological antianimal agents are those which could be employed against domestic animals to incapacitate or destroy them through disease. The main purpose of the use of antianimal agents is to indirectly affect man by limiting his food supply. Other important effects might be limitation of his animal transportation and crop cultivation capabilities and a decrease in his production of hides, wool, fats, and biological medicinal products (adrenalin, insulin, pituitary extracts, cortisone, vaccines, and antisera).

45. Targets

The main animal targets would be cattle, swine,

sheep, goats, horses, mules, and fowl. Epidemics of the animal population, known as epizootics, occur more readily than epidemics among man. Most of the infectious animal diseases are readily transmitted from one animal to another or from herd to herd by direct contact; by contact with contaminated food, water, or excreta; or by exposure to aerosols created by coughing or sneezing. Therefore, the assumption is reasonable that an enemy could, with very little difficulty, produce epizootics by disseminating relatively large amounts of infective material from aircraft or by covertly disseminating small amounts, either before or after the beginning of open hostilities.

Section II. TYPES OF POTENTIAL BIOLOGICAL ANTIANIMAL AGENTS

46. General

Some of the diseases which have potential as antianimal agents are discussed in paragraph 47 through paragraph 52. The diseases included are primarily of a viral origin, but do not discount the potential of the bacteria or the rickettsiae as potential antianimal agents. The zoonoses were defined and their potential shown in paragraphs 23 and 24.

47. *Actinobacillus Mallei* (Glanders)

a. Description. This organism is a slender, non-motile, nonsporulating, gram-negative, rod-shaped bacillus.

b. Disease Produced. Glanders, or farcy (cutaneous form), is an acute or chronic disease of equines (horses, mules, and asses) that is communicable to dogs, cats, goats, and man. It does not occur in cattle, sheep, or swine. Definite symptoms of pneumonia are present in the early stages of the acute form of the disease; however, irre-

spective of the form of the disease, lesions of the spleen and liver often occur.

(1) The acute form of the disease is limited to the mucous membranes of the nose and upper respiratory tract. It is characterized by fever; prostration; nasal discharge; ulceration of the nasal mucosa; and acute swelling of the lymph nodes, which may break down and form deep, pus-discharging ulcers and sinuses. The acute disease is usually fatal, and death occurs within 4 to 6 weeks.

(2) The chronic form has a more gradual onset than the acute form and is characterized by formation of persistent abscesses, arthritis, ulceration of the nostrils, multiple skin swellings, ulcers, nodules, and general enlargement of the regional lymph glands. Cutaneous glanders (farcy) is usually chronic.

c. Sources of Infection. Infected animals and contaminated food and water are sources of infection.

d. Modes of Transmission. Transmission is by ingestion of contaminated food and water, by direct contact with infected animals (through skin abrasions), and by inhalation of infected material.

e. Incubation Period. The incubation period is usually from 2 to 5 days but occasionally 2 to 3 weeks.

f. Susceptibility and Resistance. Equines are the most susceptible animals.

g. Prevalence. The disease is most prevalent in parts of Europe, eastern Asia, southern Asia, and northern Africa. Introduction of the infection must always be guarded against whenever an animal is brought into the herd from an external source.

h. Mortality. Acute glanders is usually fatal. The chronic form has a mortality rate of 50 to 70 percent.

i. Immunization. No immunizing agents are available for the prevention of glanders.

j. Treatment. Treatment is given only in enzootic areas. Antibiotics are not very effective, but the systemic sulfonamides are quite active in combating the infection. Prevention depends upon the early detection and elimination, by destruction, of affected animals.

k. Epidemicity. Epizootics may occur where large numbers of animals are herded together; where sanitary requirements for stabling, feeding, and watering are lax; and where diagnostic procedures are inadequate.

l. Stability. The organism slightly resists drying but is killed by direct sunlight in a few hours. It may remain alive in decaying matter for 2 to 3 weeks. It is easily killed by the common disinfectants or by heat at 180° F. for 10 minutes.

48. Foot-and-Mouth Disease Virus

a. Description. This is a very small virus which is 0.008 to 0.012 micron in diameter. Six types of the virus have been recognized.

b. Disease Produced. Foot-and-mouth disease, also known as aphthous fever, is an acute, contagious, highly infectious, febrile disease of cloven-footed animals (cattle, sheep, swine, goats, and deer). Man is only slightly susceptible and, if infected, shows only mild symptoms. The disease causes a marked and rapid loss of weight, a rapid decrease in milk production, and a severely lowered reproductive capacity. It is characterized by

acute fever and by vesicle formation on the feet and mucous surfaces of the mouth, cheeks, and udder. In most cases a long period of time elapses before surviving animals return to normal.

c. Sources of Infection. Infected animals and contaminated food, water, milk, hides, meat products, clothing of handlers, and pastures are the sources of infection.

d. Modes of Transmission. Transmission is by ingestion of food, water, milk, or other material contaminated with urine, saliva, vesicular fluid, or feces containing the causative virus or by direct contact with infected animals.

e. Incubation Period. The incubation period is usually from 1 to 4 days.

f. Susceptibility and Resistance. Cloven-footed animals, particularly cattle and swine, have a susceptibility of 80 to 100 percent.

g. Prevalence. The disease is enzootic in various parts of Europe, Asia, and South America; recent epizootics occurred in Mexico, Canada, and England. The last outbreak in the United States was in 1929.

h. Mortality. While the mortality rate in mild cattle epizootics is said to range up to 3 percent, outbreaks have been reported with a rate as high as 50 percent. The mortality rate for sheep and goats is about 5 percent. The mortality rate is higher in young stock than in adult stock of all species affected.

i. Immunization. A variety of vaccines are effective in developing an active immunity, but each vaccine is specific only against the strain from which it was prepared. Promising strides in the development and production of vaccines have been made in very recent years; however, the immunities produced are not long lasting. Recovery from infection results in a strain-specific resistance lasting about 1 year.

j. Treatment. Treatment for foot-and-mouth disease in the United States is absolutely prohibited. Under Federal law, infected animals must be destroyed. Further, prophylactic vaccines and sera must not be used. Similar regulations exist in many other countries. However, control measures using vaccine and quarantine have been employed during epizootics of the disease in Mexico.

k. Epidemicity. The disease has very high communicability. It tends to spread rapidly over a wide geographic area. The disease is controlled mainly by quarantine and vaccination of exposed

animals, vaccination of animals likely to be exposed, and slaughter of infected animals.

l. Stability. The organism is quite resistant under natural conditions. Contaminated hay and barns may remain infective for weeks; the organism may persist in moist soil for months. It is resistant to low temperatures but is destroyed within 30 minutes by heat at 140° F. or above. It resists drying for several weeks. A 2 percent potassium hydroxide (lye) solution is a practical decontaminant.

49. Rinderpest Virus

a. Description. Rinderpest virus is a very small virus.

b. Disease Produced. Rinderpest is also known as cattle plague. It is an acute, febrile, highly contagious, fatal disease of bovine animals (cattle, oxen, water buffalo); sheep and goats are fairly resistant to infection. It is characterized by sudden onset with high fever, inflammation of the digestive tract, inflammation and erosion of the mucous membranes of the mouth, bloody diarrhea, stupor, and emaciation. Death may occur within 7 to 12 days after onset. The virus is present in practically all the body tissues and fluids of infected animals.

c. Sources of Infection. Infected animals are the sources of infection.

d. Modes of Transmission. Transmission is by ingestion of food or water contaminated by urine, feces, saliva, or eye and nasal secretions from infected animals, or by direct contact with infected animals.

e. Incubation Period. The incubation period is from 3 to 9 days.

f. Susceptibility and Resistance. Cattle, oxen, and water buffaloes are almost completely susceptible unless they are native to an enzootic area or have survived the infection, in which case resistance is high.

g. Prevalence. The disease is commonly found worldwide, except for the Western Hemisphere. It is enzootic in parts of Africa and Asia.

h. Mortality. The mortality rate ranges from 15 to 95 percent, depending on group or herd susceptibility.

i. Immunization. Killed virus vaccines are costly to produce, have a short storage life, and produce immunity for less than 1 year. A good

immunizing serum can be prepared which confers a passive immunity of short duration.

j. Treatment. Massive doses of antiserum may be used to protect susceptible animals but are of little value after symptoms appear.

k. Epidemicity. Epidemicity is very high in nonimmunized animals; the disease is highly contagious from animal to animal and tends to spread gradually over wide areas.

l. Stability. The virus will survive for nearly 3 months under controlled optimum conditions. Exposure to heat at 140° F. kills it within a few minutes. It will resist drying and sunlight for only 1 or 2 days; however, when it is freeze-dried, it will remain viable for months. Effective disinfectants are 2 to 5 percent phenol and 0.1 percent bichloride of mercury.

50. Hog Cholera Virus

a. Description. This virus is 0.025 to 0.080 micron in size.

b. Disease Produced. Hog cholera, known as swine fever in Europe, is a highly acute, contagious, febrile disease of swine. Death may occur in 7 to 10 days. It is usually chronic in older swine. The chronic form of the disease is characterized by high fever, purulent discharges from the eyes, diarrhea, loss of appetite, severe hemorrhages, viremia, and extreme weakness.

c. Sources of Infection. Infected swine are the sources of infection.

d. Modes of Transmission. Hog cholera is transmitted principally by intimate contact with sick animals and directly or indirectly with fresh secretions and excretions. Probably one of the most frequent ways by which cholera reaches isolated swine herds is the practice of feeding kitchen scraps or garbage. Aerosol transmission is possible. Hogs that have recovered from the disease are possible carriers.

e. Incubation Period. The incubation period is from 5 to 7 days.

f. Susceptibility and Resistance. The disease is infectious only for susceptible swine (either domestic or wild). The percentage of exposed swine that are susceptible is 70 to 100. Animals that recover from the disease are immune.

g. Prevalence. Hog cholera is worldwide and is the greatest menace which swine raisers have to contend with. It is widespread in the swine-

raising areas of the midwestern United States and has been reported in Europe, Africa, Asia, and Australia.

h. Mortality. The mortality rate is 90 percent in infected animals.

i. Immunization. Several excellent active and passive immunizations have been developed and are available.

j. Treatment. Early administration of immune serum is the best treatment but is only moderately effective.

k. Epidemicity. This highly contagious disease spreads rapidly and easily among swine. It tends to spread gradually over a wide geographic area. Control of the disease requires rigid measures of isolation and disinfection whenever an outbreak occurs, dietary controls, and the development of prophylactic immunities.

l. Stability. Hog cholera virus is stable for months at low temperatures when suspended in a liquid medium. It is destroyed by the use of 1 to 2 percent caustic soda to clean premises; exposure to 2 percent cresol for 1 hour; exposure to a temperature of 149° F. for 1 hour; or by natural exposure where drying of the virus is complete. It is resistant to phenol and glycerin.

51. African Swine Fever Virus

a. Description. This virus is small and very resistant to environmental changes.

b. Disease Produced. African swine fever, also known as wart hog disease, is a highly contagious and very acute disease of domestic swine. It is characterized by fever; pronounced hemorrhages of the lymphatic glands, the kidneys, and the mucosa of the alimentary tract; and by marked cyanosis of the skin. Clinically, African swine fever is similar to but more acute than hog cholera; its immunology is distinct from that of hog cholera.

c. Sources of Infection. The bush pig and wart hog harbor the virus but usually do not manifest symptoms. Contact with these wild pigs apparently initiates the infection in domestic swine. Once the infection is established, it spreads rapidly by contact.

d. Modes of Transmission. African swine fever is transmitted by contact with urine and feces from infected pigs, by feeding raw garbage contaminated with the virus, or by pigs actually eating carcasses of virus-carrying wild pigs; it is

mechanically spread by caretakers and others who leave infected premises without taking proper precautionary measures. Investigations show that transmission from wart hogs to domestic pigs may possibly be by an insect vector; however, the identity of the vector has not been established. In a few cases where domestic pigs have survived the disease, there is evidence that they may act as carriers for as long as 2 months after apparent recovery.

e. Incubation Period. The incubation period is usually 4 to 7 days after contact with infected pigs.

f. Susceptibility and Resistance. The disease may be expected to occur in 100 percent of susceptible domestic swine. The disease is of such a highly contagious nature that usually, in a few days after the first case is noticed, the majority of the pigs in a herd becomes infected. It has been frequently noted that the virus from the wart hog or wild pig takes some time to attain high virulence; the occurrence of an isolated death is followed a week or so later by one or two more deaths and then, after a further interval, the appearance of many cases with rapid spread.

g. Prevalence. African swine fever is known to exist on the African continent and in Spain and Portugal. Most cases have been confined to East Africa and the Union of South Africa.

h. Mortality. Fatalities exceed 95 percent and approach 100 percent.

i. Immunization. Attempts at immunizing swine against this virus have been, for the most part, unsuccessful. Even pigs that have survived infection are not consistently immune to subsequent exposures. Hog cholera antiserum affords no protection against this disease. Immune serum prepared from the African swine fever virus offers only slight protection.

j. Treatment. At present there is no effective treatment for the disease.

k. Epidemicity. The disease is highly contagious. It is prevalent in areas where opportunities exist for cohabitation between wild and domestic hogs. Control of the disease has been successful in East and South Africa by immediate slaughter of all infected and exposed animals, disposal of all carcasses by burning or deep burial, disinfection (usually with lye) of the infected premises, and quarantine of infected areas. Measures to prevent contact of domestic swine with wild pigs have

resulted in a marked decrease in the number of cases of the disease.

l. Stability. This virus is very stable at low temperatures; it has remained viable after storage in a cold, dark room for 6 years. It is killed by sunlight; however, it will remain viable in infected carcasses, food, and water for some length of time.

52. Newcastle Disease Virus

a. Description. This virus is 0.08 to 0.12 micron in size.

b. Disease Produced. Newcastle disease, also known as pseudo fowl pest and pneumoencephalitis, is an acute, highly contagious, febrile disease of fowl (chickens, turkeys, and pheasants). The disease is of short duration and may not be recognized in adult birds. It is characterized, particularly in young birds, by severe disturbances of the respiratory and nervous systems, including difficult breathing, depression, stupor, twitching of the head and neck, marked weakness, twisted neck, and perhaps paralysis. Egg production is sharply interrupted for weeks.

c. Source of Infection. Infected fowls are sources of infection.

d. Modes of Transmission. Transmission is by direct contact, by ingestion of infected food or water, from equipment contaminated with the virus (from infected organs or secretions), and by inhalation of contaminated dust. The virus is also present in eggs laid by birds that have survived an acute attack.

e. Incubation Period. The incubation period is usually from 4 to 8 days, although it may be as long as 14 days.

f. Susceptibility and Resistance. The infectivity rate ranges from 50 to 90 percent. Chickens of all ages and turkeys are highly susceptible; pigeons, geese, ducks, other barnyard fowls, and some free-flying birds are also susceptible.

g. Prevalence. The disease is worldwide.

h. Mortality. The mortality rate ranges from 10 to 95 percent. The disease found outside the United States in young birds is nearly 100 percent fatal. Virus strains found in the United States and recently in England are usually much less fatal.

i. Immunization. Vaccination is widely used. Live and killed vaccines are available commercially. Recovery from the disease confers immunity.

j. Treatment. No treatment has been developed.

k. Epidemicity. The disease is highly communicable and tends to spread gradually over wide geographic areas. Greatest incidence of the disease in the United States is in the winter months. Control measures consist of vaccination and maintenance of high standards of sanitation.

l. Stability. The virus remains viable for years when dried in the frozen state (lyophilized); it is readily destroyed by pasteurization. Effective disinfectants include 3 percent phenol, 3 percent cresol, and 2 percent sodium hydroxide solutions.

CHAPTER 6

POTENTIAL BIOLOGICAL ANTIPLANT AGENTS AND ANTIMATERIEL AGENTS

Section 1. INTRODUCTION

53. General

Plant production is essential to the maintenance of life of man and animals on this planet. Food, clothing, some essential drugs, and many luxuries are directly or indirectly dependent upon growing plants. Plants, like man, have been plagued from the beginning with numerous diseases, and history is dotted with recordings of human suffering caused by naturally occurring plant disease epidemics (epiphytotics). Although great advances have been made in recent years in plant disease control, losses of several billion dollars occur each year. It is estimated that fungal diseases alone destroy enough food annually to feed several hundred million people. With rapid increases occurring in the human population, food and money losses due to epiphytotics become ever more important. Biological antiplant agents, living organisms that cause disease or damage to plants, may be used intentionally by an enemy to attack food or economically valuable (cash or money) crops, thereby reducing a nation's ability to resist aggression.

54. Targets

Food crops of importance include potatoes; sugar beets; truck farm vegetables; soybeans; sorghum; rice, corn, wheat, millet, and other cereals; and fruits. Economically valuable crops of great importance are coffee, cotton, rubber, hemp, and lumber. To a great extent, selection of targets would be determined by their relative importance in the national diet and economy. Epiphytotics in the centers of agricultural production could cause product scarcity, with serious national and international consequences. For example, naturally occurring late blight of potato disease was a factor in the defeat of Germany in World War I by the destruction of about one-third of the potato crop; potatoes made up a large part of the wartime diet of the Germans. This reduction in the already scanty food supply contributed to the

breakdown in physical endurance and morale. Plant diseases can cause or aggravate serious shortages in wartime because fewer varieties of crops are likely to be grown, greater quantities are needed, and substitutes may be unavailable or unsatisfactory. Diversion of the chemicals necessary in the manufacture of fertilizers and insecticides to other uses reduces crop yields and hampers control of diseases.

55. Types

a. Fungi.

(1) Pathogenic fungi cause many serious plant diseases and offer great potential as anti-plant agents. Some fungal diseases of plants are cereal rusts, grain smuts, potato late blight, rice blast, and southern blight of row crops. These fungi reproduce by forming large numbers of spores that are easily spread by the wind and insect vectors, causing epiphytotics. Fungal infections are initiated by spore germination upon the host and subsequent penetration by the germ tube through natural openings in plant leaves and the intact surfaces of leaves and roots. Minute amounts of fungal spores are sufficient to initiate an epiphytotic; therefore, small quantities can be spread over large areas enhancing their potential as biological antiplant agents.

(2) Infectivity of fungal antiplant agents will be affected by environmental conditions and the age, condition, and variety of the host. This indicates that the time of the attack during the growing season is of utmost importance. Most fungal antiplant agents are host specific; i.e., usually each species of fungus is limited to a few closely related host plant species. Some races of species of plant pathogenic fungi are even limited to specific varieties of a particular species of host. This allows a considerable amount of host selectivity by an enemy.

b. Bacteria. About 160 species of bacteria are known to be pathogenic to approximately 150 gen-

era of flowering plants. Bacterial parasites on plants are rod shaped, and may or may not be motile. The severe effects of bacterial attack are due to the fact that they develop in plant tissues in large numbers and secrete either toxins that kill host cells, enzymes that deteriorate plant materials, or growth stimulating substances that lead to cancerous cell development. No species of bacteria is known to directly penetrate the waxy substance covering plant surfaces. In order that infection may occur, bacteria must be carried into the tissues of the host plant either by being drawn into natural plant openings or wounds or by being introduced from the mouthparts of feeding insects. In many cases the lesions of bacterial diseases become covered with watery masses or droplets of bacterial ooze containing millions of bacteria. The bacteria cannot be readily dislodged and blown about by the wind; but when the ooze is softened by rain or dew, splashing water or insects serve to carry the bacteria to new infection sites.

c. Viruses. All crops of economic importance suffer considerable losses due to viruses. These losses result from either yield reduction or lowered market value. Symptoms expressed by viral infected plants vary greatly from chlorotic mottling of the leaves to stunting, lesions, leaf rolling, or even death of the plant. Some plant viruses can be mechanically transmitted by the rubbing of juice of an infected plant into the leaves of a healthy one; however, in nature, the majority of plant viruses are spread by insects.

d. Nematodes. Nematodes are roundworms that may be free living or parasitic on animals or plants. The free living species and those parasitic on plants are usually microscopic. The body structure is tubular, with the digestive system enclosed by an outer layer of tough skin overlaying a muscle layer. The head contains a stylet that can be extended through the mouth to penetrate plant cells upon which the nematode feeds. Plant parasitic nematodes live in soil and usually feed on the underground portion of the host, causing it to wilt, yellow, swell, or to die. Severe nematode damage can occur in any part of the United States and in some areas reduces the yield of certain crops as much as 25 to 50 percent. Eradication of nematodes from an area is costly and difficult.

e. Insects. Insects can feed on plants causing mechanical damage, or they can serve as vectors for plant pathogenic microorganisms. Insects reduce yield, lower quality, increase cost of production and harvesting of crops, and require outlays for materials and equipment to apply control measures. Cereal and forage crops are attacked by many insects such as corn earworm, chinch bug, grasshoppers, velvethead caterpillar, and greenbug. Among the many kinds of insects that attack vegetable and truck farm crops are aphids, leafhoppers, beetles, weevils, caterpillars, thrips, spider mites, and cutworms. The potential use of insects as antiplant agents is limited by several factors. Raising insects in quantity would be difficult and expensive; insects are difficult to disseminate and control; and they are susceptible to insecticides.

56. Defense Against Antiplant Agents

Control or defective measures against naturally occurring or intentionally employed plant pathogens may be divided into three major categories—protection, eradication, and resistance. Protective measures include protecting the host from exposure to the pathogen or from environmental factors favorable to disease development. This encompasses measures designed to keep the pathogen from entering the area in which the host is growing (quarantine, embargo, inspection of planting stocks, dusting and spraying of foliage with chemicals) or by growing the host in areas where the environment is unfavorable for pathogen development. Eradication is concerned with eliminating the pathogen after it has become established in the area where the host is growing. These measures include eradication of alternate hosts; eradication of overwintering debris as sources of primary inoculum by rotation or sterilization; and eradication from growing parts of the host by chemicals after infection has occurred. Disease resistance is used as a means of control by the development of strains of the host, through hybridization and/or selection, which are more resistant to one or more pathogens. Acquired immunity, comparable to but not analogous with that used widely with animals, is very limited in plants.

Section II. FUNGI

57. *Phytophthora Infestans* (Late Blight of Potato)

a. Description and Method of Infection. This fungus, one of the lower fungi, destroys the foliage and fruit or tubers of tomatoes and potatoes. The damage results from the fungus growing through tissues and causing disruption and rotting. During periods of high humidity, this fungus develops specialized sporebearing structures on the outside of the infected plant tissues. These spores (sporangia) are easily detached and become airborne. Within these sporangia, motile, swimming bodies called zoospores are developed and are released when the sporangia land in free water such as dew. The swimming zoospores move to the plant surfaces and germinate to produce infective germ tubes. These germ tubes can penetrate through the plant surfaces or through natural openings.

b. Symptoms. Late blight of potato first appears as large, water-soaked foliar lesions. A fine, white moldlike growth appears as sporangia are produced. Foliage damage reduces production; tuber rot and fruit rot cause additional reductions. Crop losses from 50 to 100 percent have been recorded.

c. Sources of Infection. Initial infection usually results from using infected tubers or plants for planting.

d. Susceptibility and Resistance. Potatoes and tomatoes are the principal hosts. Varietal resistance exists; however, no variety is resistant to all races of the fungus.

e. Influencing Factors. The development of late blight of potato is critically dependent upon climatic conditions. Moist cool nights, warm daytime temperatures, and free moisture remaining on foliage for about 4 hours are the ideal conditions for disease development.

f. Prevalence. This disease is of major importance in the cooler, humid potato-growing regions of the temperate zone where climatic conditions are favorable for epiphytotic development. The Irish famine of the middle 1800's resulted from the destruction of the potato crop; this same pandemic outbreak affected most of Europe and some of North America.

g. Control. While varietal resistance and careful cultural practices reduce crop losses from late blight, major emphasis is still on the use of pro-

TECTIVE fungicides prior to infection. The best time for fungicidal applications may be determined by following weather reports which will indicate the optimal conditions for disease development.

58. *Piricularia Oryzae* (Rice Blast)

a. Description and Method of Infection. *Piricularia oryzae*, a fungus of the group without a known sexual stage (*Fungi imperfecti*), is a known pathogen of rice and a few other grass plants. However, it also will grow saprophytically on many artificial media. As the fungus grows, it produces asexual spores (conidia) that become detached and airborne and which are capable of infecting new host plants. The spores germinate on host tissues, make direct penetration, and invade all tissues. Sporebearing stalks (conidiophores) are pushed up through invaded tissues where they produce spores that can be blown to adjacent plants. An estimate has shown that each square centimeter of infected leaf tissue could produce about 80 million spores.

b. Symptoms. Lesions on rice plants vary in size from pinpoint to many square millimeters; they are ellipsoid in shape and zonate (eye-spot) in appearance. Invaded tissues die after cellular disruption. Infections in the whorl stage of development will involve several layers of leaf tissue. Rice plants are most severely damaged in the seedling stage and as the head (panicle) is developing. These later infections involving the neck area of the head prevent normal development of the grain (blasting). In severe neck infections, the stem is broken and the head will drop off, causing the loss of any grain that was developed.

c. Sources of Infection. Infected plant residues from previous infections are the principal sources of infection. However, other grass hosts that are infected with the fungus in the vicinity of rice fields can also be potential sources of infection.

d. Susceptibility and Resistance. Rice varieties vary in their degree of susceptibility to particular types of *Piricularia oryzae*; however, probably no variety possesses resistance to all races of the fungus.

e. Influencing Factors. Free water, either dew or rain, for 8 to 10 hours is necessary for spore germination. Maximum pathogenic development and sporulation occur at about 80° F. with above

90 percent relative humidity needed for spore production. The amount of infection is directly correlated with the amount of available nitrogen in the plant. Cooler temperatures, from 60° to 70° F., permit accumulation of nitrogen and enhance infections.

f. Prevalence. Blast is a serious disease of rice in most paddy rice-growing areas, and much effort has been devoted in such areas to develop varieties possessing resistance to locally occurring strains of the fungus. Crop losses of from 50 to 90 percent have been recorded.

g. Control. In most areas, the development of resistant varieties of rice is considered the only control measure. Destruction of previously infected plant debris, rotation of crop land (which is not practical in most rice areas), and regulation of nitrogen supply have limited value in preventing serious losses.

59. Erysiphe Graminis (Powdery Mildew of Cereals)

a. Description and Method of Infection. This fungus belongs to the group which forms prominent sexual structures called asci and are known as *Ascomycetes*. This fungus attacks most grass crops, including wheat, barley, oats, and rye, in the cool, humid areas of the world. The fungus grows on the surface of the foliage and penetrates the tissues directly through cell walls to obtain its necessary nutrients. Asexual spores (conidia) are produced in long chains which detach easily, become airborne, and infect additional plants.

b. Symptoms. The powdery, white fungus growing on the foliage gives this fungus its name "mildew." In later stages the fungal growth becomes gray-tan in color, with minute black bodies visible to the naked eye imbedded in it. These black bodies are the developing sexual bodies (asci) of the fungus.

c. Sources of Infection. This fungus overwinters on crop debris in previously infected fields. While ascospores that develop from overwintering asci may be important, most infections probably arise from asexual spores that are produced from old fungal mats.

d. Susceptibility and Resistance. Improvements of most crops have developed varieties that possess resistance, but no variety has resistance to all the strains or types of the fungus. Most host crop are attacked by a specialized form of *Ery-*

siphe graminis, but the symptoms and mode of infection are similar in all strains.

e. Influencing Factors. Temperatures from 60° to 70° F. are most favorable for disease development; but the spores will germinate at all temperatures from freezing to about 95° F., with from 50° to 70° F. being ideal. Alternate wetting and drying of infected foliage is considered necessary for spore development; but once on susceptible host tissues, the spores will germinate and grow over a wide range of relative humidity. The degree of infection is thought to be dependent upon the vigor of host growth prior to infection, with more vigorous growth associated with higher infections.

f. Prevalence. This disease is found in all areas of the world where environmental factors are favorable during the crop-growing seasons.

g. Control. While the development of disease resistant varieties offers the best control, the destruction of crop residues by plowing or burning and the rotation of crop lands reduce infections. The use of fungicides containing sulfur has been demonstrated to be beneficial even after infection has taken place; however, this has not been economically feasible in most crop-growing areas.

60. Puccinia Graminis (Stem Rust of Cereals)

a. Description and Method of Infection. *Puccinia graminis* attacks many wild and cultivated grasses, including economically important cereals such as wheat, oats, barley, and rye. Damage to cereals results from foliage and stem infections which reduce photosynthetic efficiency and increase water loss. Crop losses result from both reduced quantity and quality of grain. *Puccinia graminis* has several spore types of which the uredospore (summer spore or "repeater" spore) infects the wheat plant and may cause an epiphytotic. These spores are spiny, golden-brown ellipsoidal bodies, 13 to 24 microns in width by 21 to 42 microns in length. Upon germination on host foliage, penetration is through the normal openings (stomata) in the leaves. The fungus grows throughout infected tissues and depletes them of nutritive materials, and (more serious) ruptures the water-containing tissues of stems and leaves.

b. Symptoms. On cereals, disease first appears as minute flecks or immature pustules which develop into rough linear lesions, having a brick-red color, as the uredospores are developed. These lesions rupture the epidermis of the host. Late in

the infective stage, many of these lesions will become black as overwintering black-walled teliospores are produced (on old cereal plants).

c. Sources of Infection. While uredospores are the significant source of infection for cereal crops, teliospores that overwinter in infected crop residue initiate basidiospores which are capable of infecting barberry plants. On the barberry plant, a sexual stage of this fungus is completed and aeciospores are produced and are disseminated by the wind. Aeciospores infect the cereal plant, and ultimately a new series of uredospores is developed. This portion of the disease cycle requires that the cereal and the barberry grow near each other. The production of uredospores takes place on the young cereal plant once initial infection occurs. Subsequent crops of uredospores are produced every 10 to 12 days. It is this "repeater" spore, the uredospore, which causes the greatest damage because it may result in an epiphytotic condition. In the United States and many other cereal-growing areas, the continental movement of uredospores by the wind from one cereal-growing section to another accounts for the major portion of cereal infections. The winds from the south in the spring blow the spores from areas of northern Mexico and the southern United States to progressively infect the wheat belt of the Great Plains states and of Canada.

d. Susceptibility and Resistance. Most of the cereal crops are infected by a special type of stem rust. Within each species of stem rust, there are a number of strains of spores that are capable of

attacking certain varieties of wheat. There are over 100 known strains of spores and no one wheat variety possesses resistance to all strains.

e. Influencing Factors. Temperatures between 55° and 90° F., with optimal range of 70° to 80° F., are required for pathogenic development and uredospore production. This fungus requires the presence of moisture on the foliage (preferably in the form of heavy dew) for uredospore germination. Heavy rain following spore deposition will tend to wash the spores from the foliage prior to infection. Once infection has been initiated, further development of stem rust is independent of external moisture. However, when the water-containing tissues are ruptured, this disease will cause the greatest crop losses when soil moisture supplies are low.

f. Prevalence. Stem rust is known in every part of the world where the grain cereals are grown. In the United States, losses of 70 to 90 percent have been recorded, with an average annual loss of about 3 to 5 percent. The occurrence of this disease is recorded in all reports of ancient plant husbandry, with the Bible relating its effects. The ancient Romans even celebrated a holiday to ask the rust god *Rubigo* to protect them from its scourges.

g. Control. The culture of resistant varieties offers the only practical control, both by limiting infection and by reducing the numbers of spores. Fungicidal protection can be of limited value, but it is too expensive for practical use.

Section III. BACTERIA

61. General

The bacteria cause several plant diseases; however, only *Erwinia carotovora* is included.

62. *Erwinia Carotovora*

a. Description and Method of Infection. The bacterium *Erwinia carotovora* causes the most destructive disease of vegetables in storage; under moist conditions, this bacterium will also attack crops in the field. The organism gains entry through wounds, and it will grow when moisture is abundant. As the bacterium grows, it produces an enzyme which dissolves host cell walls, causing them to become watery and slimy and to separate from one another.

b. Symptoms. The disease is first indicated by

a softening of the tissues, usually accompanied by a watery exudate or, under dry conditions, by a rapid drying.

c. Sources of Infection. This bacterium occurs naturally in most soils, but it is especially abundant where crop debris or storage debris accumulates.

d. Susceptibility and Resistance. This organism is capable of attacking many types of crops. Carrot roots, potato tubers, onion bulbs, celery stalks, and cabbage and lettuce heads are the most susceptible.

e. Influencing Factors. *Erwinia carotovora* will grow over a wide range of temperatures but is very dependent upon high humidity for rapid disease development. The presence of wounds is

essential for infection; harvest wounds, storage bruises, or insect punctures are the most common wounds. Under some conditions, insects act as inadvertent carriers by eating on infected tissues then transferring the bacterium on their mouth-parts to uninfected tissues.

f. Prevalence. This bacterium is distributed worldwide and is a normal part of the soil anywhere that plant tissues are incorporated into the soil. High populations are associated with crop and storage debris.

g. Control. Care in handling and storing of vegetables to prevent bruising and wounding is essential for control. The practice of using bactericidal washes followed by drying of crop products may be of value, although washing without the use of bactericide spreads the organism and provides needed moisture for growth of the bacteria. Sanitation in growing, handling, and storage is considered essential for preventing serious losses.

Section IV. VIRUSES

63. Tobacco Mosaic Virus

a. Description and Method of Infection. The virus *Marmor tobaci* causes the most common disease of tobacco and is also known to attack tomato, pepper, and other cultivated and wild plants. This virus can be transmitted from infected to healthy plants by direct contact, insect vectors, cultivation equipment, and by the hands of field workers. This virus is infective at dilutions of one part per million and can withstand heat at 194° F. for 10 minutes. Infected plant juice has remained infective for 25 years.

b. Symptoms. This disease can be detected first by downward curling or distortion of the youngest leaves, with a chlorosis (yellowing) generally being present. As the leaves grow they develop irregular mottled, crumpled areas, usually with areas of normal and chlorotic tissue on the same leaf (mosaic). Infected plants commonly have abnormal flowers appearing, with a stunting of plants and foliage.

c. Sources of Infection. Infected plant debris and both field and processed tobacco (cigarettes, cigars, and pipe tobacco) contain high amounts of infected plant tissue. Insect vectors are a common method for plant-to-plant spread of the infection in the field. Workers in tobacco and tomato fields are also responsible for initial infections and field spread.

d. Susceptibility and Resistance. The development of resistant varieties is in progress. However, as yet only a few acceptable types that possess adequate resistance are available.

e. Influencing Factors. This virus is infective under any conditions that will permit plant growth; infection is dependent only upon a source of infection and a means of spread.

f. Prevalence. Tobacco mosaic is recorded in all tobacco-growing areas of the world.

g. Control. Extreme care and sanitation during crop production, including steam sterilization of seed beds, nonuse of tobacco products by workers, and the control of insect vectors, are essential to prevent infection or to reduce its spread. The use of resistant varieties will do much to prevent crop losses and to reduce sources of potential infection.

64. Curly Top Virus of Sugar Beets

a. Description and Method of Infection. The virus *Chlorogenus eutetticola* causes one of the major diseases of sugar beets and is known to infect many other plants, both wild and cultivated. It caused almost complete elimination of the sugar beet industry in the United States before control measures were developed. This virus is inactivated by heat at 167° to 176° F. and by dilutions of one part to 20,000; but it is resistant to the action of alcohol, high pH, and freezing for 18 months. It has remained infective in dried tissues for 8 years and in dried plant sap for 10 months. The only known method of natural infection is through the insect vector *Eutettix tenellus*, the beet leafhopper.

b. Symptoms. The symptoms of curly top of sugar beets vary, depending upon the stage of maturity when infected. Infected seedlings die rapidly. Older plants, upon being infected, will show a variety of symptoms; generally, these are a distorted thickening with inrolled edges of younger foliage and a yellowing or chlorosis of older leaves. Leaves become a dull-green color and eventually fade and die. The vascular bundles of leaf petioles (stems) and developing roots will develop necrosis, which appears as dark concentric circles in these tissues.

c. Sources of Infection. This virus overwinters primarily in perennial wild (weed) hosts and is transmitted to economic crops by the leafhopper feeding on wild hosts and subsequently upon the crop plants.

d. Susceptibility and Resistance. While sugar beets are the main host crop, tomatoes, cucurbits, beans, and a wide assortment of wild hosts are susceptible. Resistance has been developed in sugar beets and other crops that gives a type of tolerance to the disease and permits their production without serious loss. However, most of these resistant varieties still can be infected and

can serve as reservoirs of infection for unprotected crops.

e. Influencing Factors. The presence of the beet leafhopper *Eutettix tenellus* is the major factor in the spread of this virus.

f. Prevalence. At present, this disease is confined to the North American continent; however, a similar virus is known in South America.

g. Control. Control of the insect vector is of major concern. Use of resistant varieties alleviates some loss in areas where the disease occurs.

Section V. POTENTIAL BIOLOGICAL ANTIMATERIEL AGENTS

65. General

Antimateriel agents are organisms which degrade or break down some item of materiel. Most of the materiel damage done by microorganisms is a result of natural contamination which grows only under very special conditions of temperature and relative humidity. It would be difficult for an enemy to effectively utilize an antimateriel agent because of the uncertainties of any significant

success. Our primary enemy is Mother Nature herself.

66. Types

Fungi are responsible for damage to fabrics, rubber products, leather goods, and foodstuffs. Some bacteria can utilize petroleum products as an energy source, causing residues which might clog fuel or oil lines. Some bacteria produce highly acidic compounds which cause pitting in metals.

CHAPTER 7

DISSEMINATION

67. Introduction

The term "dissemination" as used in this manual refers to the intentional release of a biological agent so that it will reach the portals of entry of target personnel in a viable and virulent state. Based on the portals of entry, the characteristics of agents used, and the results desired, certain methods of dissemination are feasible for biological attack. The effectiveness of these methods is determined by physical and environmental factors which limit the ability of the agent to establish infection. Dissemination methods are related to the existence of three primary portals of entry through which pathogens may be introduced into the body to establish infection. These portals are the respiratory tract, the skin, and the digestive tract (para 18).

68. Aerosol Respiratory Method

The exposure of the respiratory tract to a biological agent is accomplished by disseminating the agent as an aerosol. An aerosol is comprised of finely divided particles, either liquid or solid, suspended in a gaseous medium. Examples of common aerosols are dust, fog, and smoke. A biological agent aerosol is defined as an airborne suspension of particles containing living pathogenic organisms.

a. Characteristics of Aerosol Dissemination.

(1) *Difficulty of detection.* A biological agent aerosol in field concentrations cannot be detected by the physical senses.

(2) *Capability of penetration.* Aerosol particles tend to diffuse in much the same manner as a gas. The aerosol cloud travels with the wind and is capable of diffusing into nonairtight structures that are not equipped with adequate filtering devices.

(3) *Difficulty of diagnosis.* The classical symptoms of a disease associated with a particular pathogen are based on the establishment of an infection through a "normal" portal of entry.

Certain pathogens are capable of causing infection through more than one portal of entry. Infection established through an "unusual" portal of entry might result in a group of symptoms creating difficulties in diagnosis. Two or more organisms might be simultaneously disseminated, which would also increase the difficulty of diagnosis. The increased time required for diagnosis and associated therapy adds to the effectiveness of the aerosol attack.

(4) *Increased severity and mortality rate.* Certain diseases have altered incubation periods, incapacitation times, and mortality rates when the causative microorganism enters the body through an unusual portal of entry. This is the result of the organism diffusing directly into the bloodstream and being carried by the blood directly to the body tissues. The data in figure 2 illustrate the difference in the mortality rates of selected diseases when the disease was acquired through the respiratory tract.

Disease	Cutaneous (Skin) (Normal) (Percent)	Pulmonary (Lungs) (Unusual) (Percent)
Anthrax	5 to 20	99
Plague	20 to 30	95

Figure 2. Public Health Service mortality rates.

(5) *Massive overdoses.* Personnel might be exposed to massive overdoses of an agent through the use of an aerosol. Thus, the acquired immunities of target personnel possibly might be overcome by the use of selected agents.

(6) *Increased susceptibility.* Man has a constant requirement for oxygen and therefore he is breathing continually. This increases the probability of contacting an airborne organism.

b Particle Size. For the biological agent aerosol to be effective, it must reach target personnel. The microorganisms must be alive and capable of producing infection and must be in a particle size which can enter the respiratory tract and be retained in the deep portions of the lungs (alveolar bed) where infection is most likely to occur. Particle size is a critical factor in lung infections. The natural defensive features of the upper respiratory tract, such as mucous membranes, shell-type compartments within the nose, and cilia of the trachea and bronchial tree, are capable of impinging or trapping most particles larger than 5 microns in diameter. Particles smaller than 1 micron usually are exhaled from the lungs before they have time to settle. Particles in the size range from 1 to 5 microns are much more capable of passing through the defensive barriers of the upper respiratory tract and of being retained in the lungs than those below or above this size range.

c. Formation of Aerosol Particles. There are three general methods of forming biological agent aerosols. Particles in the proper size range can be formed by physically breaking up a substance. This can be accomplished by release through a nozzle or a spray or by an explosive force.

(1) *Generator.* Particles can be formed by forcing the wet (slurry form) agent through a nozzle at a regulated pressure. Particle size is determined by the amount of pressure, the size of the orifices, viscosity of the agent, and the relative humidity. Size control of solid particles (dry form of agent) can be achieved by presizing before dissemination.

(2) *Spray.* Aerosol particles in the proper size range can be produced by releasing the agent in slurry form into a high velocity air stream. An application of this principle is spray devices used on high performance aircraft.

(3) *Explosive force.* Biological agents can be disseminated by explosive means; however, the size of the liquid particle is difficult to control, and much of the agent is destroyed by the heat and shock of the exploding munition. The use of an explosive means for aerosol production is feasible, however, because large numbers of organisms can be packaged in a munition. The total volume and agent concentration will support low efficiencies and still produce aerosols that result in adequate area coverage with high infective dose concentrations.

d. Agent Aerosol Stability. A biological agent

aerosol is most effective when the disseminated agent is viable, virulent, in the correct particle size, and the particles remain in the air. From the instant an aerosol is created, certain physical and environmental factors affect its stability. Aerosols eventually diffuse and become too dilute to be effective; environmental conditions cause the agent in the aerosol to gradually lose its ability to establish infection. This decline in aerosol effectiveness is called the aerosol decay rate which is usually expressed as percent decay (death) of microorganisms per minute. The decay rate differs from agent to agent and for meteorological conditions. Decay rate is of utmost importance in planning area coverage, troop safety, casualty effects, and decontamination operations. Some of the factors that determine aerosol stability are discussed below.

(1) *Settling.* The rate of fall of the particle is directly related to its size. The terminal velocity of a 1- to 5-micron particle is relatively small (5 inches per hour for a 1-micron diameter particle in still air). This slow settling rate and the presence of convection currents within the target area cause fallout of 1- to 5-micron particles to be negligible.

(2) *Impaction.* As the aerosol cloud moves downwind from its release point, particles within the cloud strike and stick to objects in their path. While a number of particles will impact, the overall effect is negligible. Normally, when biological antipersonnel agents are aerosolized to cover large areas, despite impaction, the passage of the biological cloud is not expected to result in a militarily significant residual hazard.

(3) *Ultraviolet radiation.* The ultraviolet radiation in sunlight kills microorganisms. In spite of the low penetrating power of ultraviolet radiation, for most pathogens its killing effect is complete and takes place in a relatively short period of time upon direct contact. Disseminating an aerosol during the hours of darkness eliminates the effects of ultraviolet radiation.

(4) *Meteorological conditions.* Meteorological conditions influence the aerosol cloud as a whole. The size of the particles within the cloud causes little difference between the density of the aerosol and the surrounding air. Therefore, the aerosol will react to the weather conditions in much the same manner as the surrounding atmosphere. Wind direction and speed, relative humidity, temperature, air stability, and precipitation may affect aerosols.

(a) *Wind direction and speed.* These determine the direction in which the aerosol cloud will travel and the size of the area that it will cover. Aerosols of biological agents with a high decay rate can be employed effectively at high wind speeds (8 to 18 knots). At these speeds, the aerosol may be carried over extensive areas during the agent survival period. Low wind speeds decrease downwind travel, which reduces area coverage. However, low wind speeds also tend to lengthen the time the aerosol is on the target and thereby increase the inhaled dose in target personnel. Multiple wind shifts, which usually occur at low wind speeds might, however, divert the agent away from the target area and thus reduce the casualty level.

(b) *Relative humidity and evaporation.* Liquid particles in a biological aerosol may be reduced in size by evaporation. A decrease in the amount of liquid in the particle creates a corresponding increase in the percentage of salts remaining in the liquid surrounding the agent. This results in an increase in osmotic pressure which tends to draw fluids out through the cell membrane, and results in dehydration of the living microorganisms. The rate of evaporation is dependent upon the relative humidity and the temperature in the environment surrounding the particle. The rate of evaporation is reduced by disseminating the agents so affected during conditions of high relative humidity. Low relative humidity is conducive to the stability of some biological agents. These agents would be disseminated during conditions of low relative humidities.

(c) *Temperature.* Temperature has little direct effect on the living portion of a biological aerosol. Indirectly, however, an increase in temperature is normally followed by an increase in evaporation rate. High temperatures (170° to 180° F.) tend to kill most vegetative bacteria as well as the viral and rickettsial agents; however, these temperatures are not normally encountered under field conditions. Subfreezing temperatures tend to freeze the aerosol after its dissemination. This freezing tends to preserve the agent and to decrease its rate of decay.

(d) *Air stability.* The temperature gradient conditions of lapse, inversion, and neutral affect the biological agent aerosol in much the same manner as they affect a chemical agent cloud. Inversion and neutral conditions are most effective for aerosol travel because the cloud is kept at a height conducive to inhalation by target personnel. Turbulence, which occurs during lapse

conditions, will cause vertical diffusion of the cloud with a resulting loss of agent to higher altitudes and reduction of area coverage.

(e) *Precipitation.* Heavy and prolonged precipitation will substantially reduce the number of agent particles in the air. The high relative humidities associated with very light rain make it less important in aerosol effectiveness than the rainout effect of heavy rainfall.

e. *Effects of Terrain on Cloud Travel.* Terrain affects cloud travel of biological agent aerosols in the same general manner as it affects chemical agent clouds. The ground contour of rough terrain creates wind turbulence which in turn influences the vertical diffusion of the aerosol cloud. Soil will have an effect only as related to heat absorption and reflection which aid in determining temperature gradients.

69. Arthropod Vector Cutaneous Method

A second portal of entry that can be utilized for biological agent employment is the skin. Penetration of the skin can be accomplished by the bite of an arthropod vector (carrier). These insects and insect-like organisms are capable of transferring pathogens to man through breaks in the skin. For the purposes of this manual, the definition of "vector" is limited to the arthropods. Vectors can be classified into two groups—biological and mechanical. Biological vectors are arthropods in whose bodies the infecting organisms must develop or multiply before they can be infective to the recipient. Mechanical vectors are those arthropods which transmit microorganisms from one host to another but are not essential to the life cycle of the parasite. The mosquitoes which transmit malaria and yellow fever are biological vectors; the black horsefly which transmits anthrax and many insects which transmit plant diseases are mechanical vectors.

a. *Vectors.* The spread of pathogens by arthropod vectors to man is well established in history. There are over 80 known viral diseases alone that are transmitted to man by arthropods. Some examples of vectors and the pathogens which they have shown to be capable of transmitting are as follows:

(1) *Mosquitoes.* The virus of yellow fever is transmitted from man to man by the bite of a mosquito. Other important mosquito-borne viral diseases are dengue fever and several types of encephalitis.

(2) *Flies*. Most varieties of true flies have sucking mouthparts, but those few which have mouthparts capable of piercing the skin of man or animals carry pathogens which cause some of the most feared human diseases. The sucking flies introduce pathogens through previously injured body surfaces or mechanically transport them on their body surfaces to exposed food and water. Typhoid fever, bacillary and amoebic dysentery, and Asiatic cholera are examples of diseases which may be spread mechanically by nonbiting flies. Pathogens transported by the biting flies include those which cause the dreaded African sleeping sickness, an infection of man, domestic animals, and wild game. The vector responsible for this disease is the tsetse fly (*Glossina morsitans*). Tularemia (rabbit fever), a bacterial disease of man and wild animals, is sometimes transmitted by the deer fly.

(3) *Fleas*. Fleas are small, wingless insect parasites of the skin of mammals and birds. Their bodies are flattened laterally, and they have mouthparts for piercing the skin. While different species show preferences for certain hosts, when hungry they will attack any warmblooded animal. This habit increases their potential to transmit disease to man. The common rat flea, *Xenopsylla cheopis*, is the vector of endemic typhus, a rickettsial disease of rats and mice. Fleas occasionally bite and infect man with the disease. *Xenopsylla* is the chief vector of bubonic plague from rats and other rodents to man. The plague bacilli, *Pasteurella pestis*, grow inside the flea's esophagus blocking it and preventing swallowing; consequently, the flea bites more often because it is seeking nourishment.

(4) *Lice*. Lice are sucking, dorsoventrally flattened, wingless insect parasites of the skin of mammals and birds. The human body louse, *Pediculus humanus*, is the vector for the rickettsiae which cause epidemic typhus and trench fever.

(5) *Ticks and mites*. These arthropod vectors are known as acarids and are not true insects. As adults, they possess eight legs while the insects have six. Most of these are merely parasitic skin pests of land vertebrate animals, but a few are important disease vectors. Certain mites transport the causative organism of scrub typhus. The wood tick, *Dermacentor andersoni*, indigenous to the western United States, is known to transmit to man the rickettsia of Rocky Mountain spotted fever, the bacterium of tularemia, and the

virus of Colorado tick fever. The dog tick, *Dermacentor variabilis*, of the eastern United States, and the lone star tick, *Amblyomma americanus*, of the central United States, can also transmit Rocky Mountain spotted fever.

b. Military Characteristics. Military characteristics can be shown by pointing out some of the characteristics of the vectors themselves and how they could apply in a military situation.

(1) The ability to penetrate the skin makes circumvention of the protective mask possible.

(2) The normal life span of the vector offers a means of obtaining persistency of the agent in the target area. Persistency can be measured as 1 to 2 months for some of the mosquitoes and 6 to 7 months for some of the fleas. A few of the ticks are able to pass the pathogen from generation to generation (mother to offspring).

(3) Female mosquitoes, which require a warmblood meal before egg production and therefore seek a warmblooded source, provide a true search-type means with which to infiltrate caves, entrenchments, and underground fortifications inhabited by personnel.

(4) The agent inside the body of the vector is protected from external environmental effects for the life of the vector.

c. Limitations. Control of the vector after release presents a problem. The vector might move out of the target area, thereby increasing the possibility of loss of control. Arthropods tend to become dormant in cold weather and are also affected by extremely high temperatures. Chemical means of control (insecticides) are available, but logistical problems and the selection of insecticide resistant strains may make this impracticable.

70. Covert (Sabotage) Method

a. Characteristics. Biological agents lend themselves well to covert or hidden operations because of detection difficulties, the variety of potential agents, the ways they might be employed, and the small amounts of materials required to cause infection. Sabotage is the direct application, by a person, of material to the target. It is generally covert in nature. A potential enemy could initiate sabotage, using biological agents prior to a declaration of war. Such an attack might allow the enemy to gain a significant advantage.

b. Targets. Covert use of biological agents might be aimed primarily at the respiratory tract

and secondarily at the digestive tract. Since many pathogens are spread naturally in food and water, these provide proven vehicles in which the saboteur could employ an agent. The respiratory tract is an excellent target for the small-scale employment of a biological antipersonnel agent aerosol.

Military targets for the saboteur might be specific troop units and installations, important headquarters, or specific individuals within an enemy country. Specific specialized industries might be paralyzed, or a whole city might feel the effects of covert dissemination of a biological agent.

CHAPTER 8

DETECTION AND DEFENSE

71. General

Defense against biological attack is comprised of several phases. The various methods by which a biological agent can be disseminated and the characteristics of the pathogens used require that a defense system consist not only of means to prevent the attack but also of means to detect the attack, to alert the personnel who are under attack, and to prevent or reduce the agent's effect upon personnel after the attack.

72. Detection

a. General. The detection of a biological agent attack is a requirement of an adequate defense system. Of primary concern is detection of biological agent aerosols, which offer the most effective method of dissemination. Unlike nuclear weapons and chemical agents, biological agents are living. They are not detectable with the five physical senses.

b. Phases of Detection. Detection can be subdivided into phases that provide information upon which maximum individual and collective protective measures can be taken. These phases are as follows:

- (1) Rapid warning, to indicate that an attack is taking place.
- (2) Sampling, to provide the material necessary for identification and in some cases to help determine the extent of contamination.
- (3) Identification, to identify the agent and help determine proper therapy for exposed personnel.
- (4) Epidemiology, to determine the extent of agent effect throughout a unit or geographical area.

c. Rapid Warning. Rapid warning requires the use of some type of automatic device or devices to give an immediate indication that biological agents have been used. A device of this nature must be extremely sensitive to detect very small amounts of agent and reliable in order to reduce

the possibility of false alarms. However, a warning may be provided by other means, such as the pattern of established warfare or recognition of the delivery system used. These could give the commander an indication that an attack is in progress.

(1) *Pattern of established warfare.* After biological agents have been employed several times, a definite pattern of usage could materialize. The time of attack, methods of dissemination, munitions, or the stage of the operation in which the agents are employed might be similar. This information will not give definite proof that a biological attack is occurring; however, if the suspected action closely parallels previous known attacks, a warning could be given.

(2) *Intelligence.* Intelligence can yield information useful in predicting a biological attack.

(a) Strategic intelligence could give the commander an estimate of the enemy's overall capabilities, limitations, and probable intentions for the employment of biological agents.

(b) Combat intelligence could give the commander an estimate of the enemy's battlefield readiness to employ biological agents.

(c) Technical and medical intelligence also have application. Technical intelligence could enable evaluation of the protective equipment of an enemy and determination of its availability to his forces. Medical intelligence might provide information concerning the status of enemy preventive medicine capabilities, medical treatment capabilities, and preparations being made in medical and related areas which might indicate imminence of attack with biological agents. For example, the extent of an enemy's immunization program might be analyzed by methods which include serum analysis (determination of antibody content in POW's) and examination of captured immunization records.

(3) *Instrumental devices.* The ideal method of rapid warning would be by an instrument capable of detecting the presence of the agent and giving an alarm.

d Sampling. The purpose of sampling is to aid in the identification of an agent by obtaining a large number of viable microorganisms relatively free from interfering materials. Sampling will be accomplished by individuals trained in sampling procedures so that uniformity will exist in the samples and the sampling data forwarded to identification personnel. Sampling must not be done indiscriminately but will be performed only after some indication that an attack has taken place. The U.S. Army standard A sampling kit is the M34 CBR agent sampling kit.

(1) Methods of collecting suspected material vary with its nature and source; that is, living or dead tissue, body secretions, water, and material from surfaces of all kinds. Sampling also varies with the method of agent release such as aerosols from spray devices or bombs. If the agent is released as an aerosol, every effort should be made to obtain a swab sample as near the point of release as possible. The number as well as the viability of the microorganisms in an aerosol will decrease progressively with the passage of time and with increasing distance from the point of release.

(2) Samples of vegetation, water, and other material on which the agent has impacted may be of value in helping confirm the identity of the agent even though the samples contain interfering contamination and yield a smaller number of microorganisms than were present in the original aerosol. Such samples should be taken as soon after release and as near the point of release as possible. Vegetation, water, and other solid and liquid samples are collected by placing contaminated portions of each in sterile containers. Samples from contaminated surfaces may be obtained by rubbing the surfaces with a sterile, moistened cotton swab and then placing the swab in a sterile capped container.

(3) Samples should be sent to the nearest designated laboratory for identification by the fastest method available.

e. Identification. The identification of microorganisms is a difficult and time-consuming process. The methods used are generally dependent upon obtaining living organisms by sampling.

(1) *Purposes.* The identification phase of detection is accomplished to determine which of the possible antipersonnel agents was used in the attack. Identification can aid in:

(a) Confirming that an attack has taken place.

(b) Determining the proper therapy to combat agent effects on exposed personnel.

(c) Estimating the expected number and type of casualties in the command.

(d) Determining time-to-casualties if time of the attack is known.

(e) Evaluating an enemy's biological capability.

(2) *Procedures.* Laboratory procedures are used to establish or confirm the identity of a microorganism. A few of the steps and methods of identification are described below.

(a) *Microscopic examination.* Microorganisms in tissue sections, smears, or suspensions of suspected material may be examined under a microscope for identification purposes. Such examinations include staining the microorganisms with dyes, which bring differentiating characteristics, such as shape, relative size, spores, capsules, and flagella, into sharper detail.

(b) *Culture.* Microorganisms may be cultivated by placing samples in sterile containers containing solid or liquid nutrient media and incubating for a specific length of time at temperatures suitable for growth. Organisms multiplying on solid media form visible masses, called colonies; the surface appearance, shape, and color of the colonies help in the identification of the organisms. In liquid media, identification of microorganisms is aided by determining the kind of nutrients required for growth and the substances produced. Cultivation of the viruses and rickettsiae requires the presence of living, susceptible host tissues.

(c) *Biochemical and biological tests.*

1. Microorganisms may be identified biochemically by cultivating them in certain media, observing the byproducts of their growth, and determining the kind of materials they consume. By adding certain chemical compounds to the media, it is possible also to differentiate the different kinds of microorganisms by observing how these chemicals influence growth or metabolism.

2. Many microorganisms may be identified by biological tests. Suitable animals are injected with the suspected organism, and clinical and post mortem observations are made on pathological changes. When a certain organism is suspected, animals which have been immunized against it and an equal number of nonimmunized animals may be inoculated with the pathogen. If the suspicion as to agent identity is correct, the nonimmunized animals will develop the disease while the immunized animals will not.

3. A third method of identification is by serological testing. This is based upon the occurrence of specific substances known as antigens in all living cells (including the cells of microorganisms). When antigens are introduced into the blood or tissues of an animal body, they induce the formation of specific reacting antagonistic substances known as antibodies. The antibodies usually appear in the blood serum. This blood serum is then used in testing for specific antigens. These antigen-antibody reactions are known as serological reactions. Serological reactions provide a means of distinguishing between different and closely related organisms; however, the procedure is usually time-consuming.

(d) *Fluorescent antibody technique.* In recent years, a great deal of research has been conducted on the fluorescent antibody (FA) technique for rapid identification of microorganisms. Identification time is reduced from a few days to a few hours by this method. The identification procedure is dependent upon the antibody attaching itself to the microorganism (antigen) for which it is specific. The antibody is tagged with a fluorescent dye before combining it with the sample microorganism. An identification is indicated when the microorganism fluoresces under a microscope using ultraviolet light illumination. This indicates that the tagged antibody has become attached to the sample microorganism. This procedure in itself is not a positive identification. Under controlled laboratory conditions, the fluorescent antibody technique produces an excellent presumptive identification.

f. *Epidemiology.* Epidemiology is the least desirable phase in determining that a biological attack has taken place from the standpoint of time; however, at the present time, it is the most positive. A considerable amount of time may be consumed before significant information would be obtained. It is, therefore, limited as a source of information upon which prompt defensive measures can be based. Epidemiology is the study of the community aspects of disease and is employed particularly during epidemics or sudden outbreaks of disease. When a large number of cases of a disease suddenly appear within an area, an investigation is conducted to determine the cause. If all natural causes for the outbreak can be ruled out, an assumption can be made that a biological attack has occurred. Initial biological attacks would probably be detected by epidemiological findings of the Army Medical Service or the Air Force Medical Service.

73. Defense

Defense must consist of measures, first, to prevent attack, and second, to combat agent effects on personnel if an attack should occur.

a. *Responsibilities.* In order to maintain an adequate defense against biological attack, certain areas of responsibility have been delineated.

(1) *Commanding General, Combat Developments Command.* The responsibility for development of concepts and guidance for the development of materiel for defense of personnel of the Armed Services against biological agents is assigned to the Commanding General, Combat Developments Command. The Chemical-Biological-Radiological Agency has the responsibility for preparation of requirements documents and guidance to the developer (Army Materiel Command) for the detectors and physical defense items (such as biological detectors, protective masks, collective protectors, and decontaminants) and for provision of doctrine for biological defense.

(2) *Commanding General, Army Materiel Command.* The responsibility for development of items of materiel in response to the requirements established by Combat Developments Command is assigned to the Commanding General, Army Materiel Command.

(3) *Surgeon General.* The responsibility for stockpiling necessary medical supplies, for care and treatment of patients, and identification of agents encountered is assigned to the Surgeon General. The doctrine for medical defense aspects is the responsibility of The Surgeon General; for example, the development of immunological procedures.

(4) *Unit commander.* In accordance with Army Regulation 220-58, U.S. Army unit commanders are responsible for the application of correct biological defensive measures and maintenance of unit protective equipment.

b. Methods.

(1) *Active defense measures.* The purpose of active defense is to prevent the attack. The measures of active defense are as follows:

(a) *Destroy the enemy's biological facilities.* By locating and damaging or destroying the enemy's research and development facilities, laboratories, manufacturing plants, stockpiles, and launching sites, his capabilities for attack can be reduced. This is an important active defense measure that will be utilized to its fullest extent

but which in all probability will not be completely effective. Biological agents can be produced in relatively small installations that can be easily hidden and would present difficult, dispersed targets.

(b) *Intercept the enemy's weapons systems.* By destroying or disrupting the enemy's attacks, the effectiveness of his operations can be reduced. This measure also will be implemented to its fullest extent, but experience has proved that some weapons systems will reach the target and effectively deliver their munitions.

(2) *Passive defense measures.* The purpose of passive defense is to reduce or minimize casualties resulting from successful biological attack. The measures used, in most cases, are based on public health practices that have proved valuable in the control of natural outbreaks of disease. The measures used, in most cases, are based on resulting from biological attack, but they will aid in reducing the number of casualties and the severity of some of the diseases. The measures of passive defense are divided into three phases: those taken before attack, those taken during attack, and those taken after attack.

(a) *Before the attack.* The measures taken before the attack are designed to minimize the effect of the agent on personnel.

1. *Personal hygiene and area sanitation.* These measures are important in routine preventive medicine and are implemented in every unit. During normal situations, these measures tend to reduce the incidence of infectious disease and to increase the general health of the individual and the unit. The infective dosage is, in part, dependent upon the physical condition of the exposed individual. Area sanitation plays an important part in defense against a biological attack by preventing rodents and other vectors from transmitting disease to previously unexposed personnel.

2. *Immunization.* The use of immunization procedures is valuable to the extent that disease symptoms are less severe or absent in immunized individuals. An enemy might hesitate to use a particular agent against troops protected by immunization because he could not be sure of the results. The assumption must not be made that immunization is the only defense needed against biological agent employment. Effective immunization procedures are not available for all the potential biological agents, and acquired immunities to some agents may be overcome if the dosage is sufficiently high.

(b) *During the attack.* The measures tak-

en by troops while under biological attack are similar to those taken while under chemical attack. The most important single item of protective equipment is the mask. A properly fitted protective mask in good operating condition will give adequate protection against aerosolized biological agents. The importance of proper fit and adjustment of the protective mask and hood cannot be overemphasized. Protective clothing is not necessary for protection against field concentrations of biological agents. Normal clothing, buttoned and arranged so that as much of the skin area as possible is covered, will give good protection. If possible, any open wounds should be bandaged.

(c) *After the attack.* The defense measures taken after attack are designed to prevent casualties resulting from secondary contamination and exposure. The primary measure is decontamination of personnel, equipment, food, and water. Personnel and equipment must be decontaminated when the situation allows. Personnel should decontaminate themselves by taking a shower with hot soapy water when it is available. In the absence of hot water or soap, physical removal of contamination can be achieved to some extent by rinsing in water. Washing with water removes about 90 percent of the microorganisms present on the skin. Soap and warm water remove about 99 percent of the microorganisms present on the skin. Cuts and other wounds should be treated as soon as possible with antiseptics. Food that has been stored in sealed containers (cartons, cans) can be made safe for consumption by decontaminating the outer container. Water poses a special problem for decontamination. Containerized water supplies such as canteens, Lister bags, or bladders can be considered uncontaminated if the outside surfaces are decontaminated or washed before opening. The only supply of adequately decontaminated water is from the Engineer Water Purification Unit. This piece of equipment is designed to remove even biological spore contamination from contaminated water sources. All water supplies that were exposed during a biological attack should be discarded and replenished with water supplied by a Water Purification Unit. In the event that water absolutely must be taken from a known or suspected contaminated water source, and a Water Purification Unit is not available, the water should be boiled vigorously for as long as possible (at least 15 minutes) and water purification tablets added. The unit medic or surgeon should be notified of the situation as soon as possible so that therapeutic measures can be taken if needed.

c. *Therapy*. Once the agent used in a biological attack has been identified, a plan of action in treatment can be initiated. Such a plan might include the use of antimicrobial drugs for prophylaxis and/or therapy, supportive care, and passive immunization.

(1) *Chemoprophylaxis*. The practice of using antimicrobial drugs, such as penicillin, the tetracyclines, and others, in an effort to prevent the initiation of an infection or to suppress certain infections during the incubation period is called chemoprophylaxis. The use of quinine in malaria is perhaps the best example; however, chemoprophylaxis demands specific knowledge of the causative agent to know which antimicrobial drug to use and how and when to administer it.

(2) *Passive immunization*. This technique is a transient immunity produced by the introduction into the patient's system of blood serum or globulin of animals already immune. The injection of a dose of sera containing antibodies leads promptly to a maximal circulating concentration

of the antibody or antibodies. Various procedures for passive immunization may include:

(a) Injection of serum from convalescent patients.

(b) Injection of serum from persons or animals hyperimmunized against the disease.

(3) *Chemotherapy*. Some examples of chemotherapeutic agents are antibiotics (penicillin, streptomycin, and tetracyclines), sulfonamides (sulfadiazine, sulfamerazine, and sulfathiazole), arsenicals (neoarsphenamine, tryparsamide, and mapharsen), and others (such as quinine, atabrine, and plasmachin). The primary example here is the administration of chemotherapeutic agents after the appearance of clinical symptoms. A serious drawback is the fact that antimicrobial drugs are not effective in the treatment of all diseases, especially viral diseases. Chemotherapeutic agents retard the multiplication of invading pathogens. Chemotherapeutic agents may be classed as bactericidal, such as penicillin and streptomycin, or bacteriostatic, such as the sulfonamides and tetracyclines.

APPENDIX A

REFERENCES

U.S. ARMY

AR 220-58	Organization and Training for Chemical, Biological, and Radiological Operations
AR 310-25	Dictionary of United States Army Terms
AR 310-50	Authorized Abbreviations and Brevity Codes
FM 3-10	Employment of Chemical and Biological Agents
FM 21-40	Chemical, Biological, Radiological, and Nuclear Defense
FM 21-41	Soldier's Handbook For Defense Against Chemical and Biological Operations and Nuclear Warfare
FM 21-48	Chemical, Biological, and Radiological (CBR) and Nuclear Defense Training Exercises
TM 3-220	Chemical, Biological, and Radiological (CBR) Decontamination
TM 3-240	Field Behavior of Chemical, Biological, and Radiological Agents
TM 3-6665-268-10	Operator's Manual, Sampling Kit, CBR Agent, M34

U.S. AIR FORCE

AFR 160-62	Joint Utilization of Certain Armed Forces Medical Laboratory Facilities
AFR 160-65	Prevention and Control of Communicable Diseases of Animals
AFR 160-88	Medical Responsibility in Disaster Control
AFR 161-1	Control of Vector-Borne Diseases
AFR 161-6	Control of Communicable Diseases in Man
AFR 161-12	USAF Epidemiological Services
AFR 161-13	Immunization Requirements and Procedures
AFR 161-21	USAF Epidemiological Laboratory
AFR 161-71	Disinsection of Aircraft
AFM 160-25	Engineering Data, Preventive Medicine and Occupational Health Program
AFM 160-46	Military Sanitation
AFM 160-47	Laboratory Procedures on Clinical Serology
AFM 160-48	Laboratory Procedures in Parasitology
AFM 161-1	Flight Surgeon's Manual
AFP 160-5-4	Coccidioidomycosis
AFP 160-5-11	Prevention of Hospital Infection—Staphylococcus
AFP 160-5-17	Epidemic (Louse-Borne) Typhus
AFP 160-5-21	Q Fever
AFP 160-5-22	Viral Infections of the Central Nervous System
AFP 161-1-1	Respiratory Protective Devices
AFP 161-1-9	Immunization
AFP 161-1-13	Dengue Fever; Hemorrhagic Disease
AFP 161-21	Plague
TO 00-110-1	Chemical, Biological, and Radiological (CBR) Decontamination

APPENDIX B

TEMPERATURE CONVERSION TABLE °C. TO °F.

°C. = (°F. - 32)5/9				°F = (°C. x 9/5) + 32	
°C.	°F.	°C.	°F.	°C.	°F.
-60	-76	45	113	150	302
-55	-67	50	122	155	311
-50	-58	55	131	160	320
-45	-49	60	140	165	329
-40	-40	65	149	170	338
-35	-31	70	158	175	347
-30	-22	75	167	180	356
-25	-13	80	176	185	365
-20	-4	85	185	190	374
-15	5	90	194	195	383
-10	14	95	203	200	392
-5	23	100	212	205	401
0	32	105	221	210	410
5	41	110	230	215	419
10	50	115	239	220	428
15	59	120	248	225	437
20	68	125	257	230	446
25	77	130	266	235	455
30	86	135	275	240	464
35	95	140	284	245	473
40	104	145	293	250	482

GLOSSARY

Abortion—Premature delivery of the fetus; expulsion of the fetus before it is capable of living outside the body.

Abscess—A localized collection of pus (usually as the result of an infection) in any part of the body, together with the tissues surrounding the pus.

Acarid—A member of the order *Acarina*, a group of arachnids including the mites and ticks.

Active immunity—Immunity resulting from the production of antibodies by the individual's own body cells in response to a stimulus provided by the presence of antigen in the tissues.

Acute—Having a short and relatively severe course; arising quickly, as acute symptoms.

Aeciospore—A spore produced in an aecium (of various rust fungi). The aecium is a cuplike structure in the life cycle of a typical rust and produces spores in chains.

Aerobe—A microorganism which can live and grow in the presence of free oxygen.

Aerosol—A suspension or dispersion of small particles (solids or liquids) in a gaseous medium. Examples are mists, fogs, and smokes.

Agglutinin—An antibody which when reacted with a specific antigen causes clumping of bacteria or other cells in a suspension, rather than precipitation.

Alkaline—Having the properties of an alkali, for example, sodium hydroxide; opposed to acid. Having hydroxyl ions (OH); basic.

Amino acid—An organic compound containing both amino (NH₂) and carboxyl (COOH) groups.

Anabolism—The constructive process (chemical synthesis) by which living cells or microorganisms utilize simple substances to make more complex compounds, together with the storage of chemical energy.

Anaerobe—A microorganism that can live without air or free oxygen.

Anorexia—Lack or loss of appetite for food.

Antianimal agent—A microorganism which causes disease in animals.

Antibiotics—Substances produced by and obtained from living cells, (usually) frequently those of lower plants, such as bacteria and molds; they are antagonistic to certain other forms of life, including pathogenic organisms. Examples are penicillin and streptomycin. Some antibiotics may also be produced synthetically.

Antibody—A specific protein substance produced by the body in reaction to an antigen (a specific foreign material) such as a bacterium or a toxin; examples are antitoxins and agglutinins.

Antigen—Any foreign substance which, when introduced into the body, stimulates the formation of an antibody; and which when mixed with that antibody, reacts with it in some observable way. Antigens are usually protein in nature and frequently consist of products produced by microorganisms.

Antipersonnel agent—A microorganism which causes disease in man.

Antiplant agent—A microorganism which causes disease or damage to plants.

Antiseptic—A substance that will inhibit the growth and development of microorganisms without necessarily destroying them. Examples are alcohol and phenol.

Antiserum; antisera (pl.)—A serum containing an antibody or antibodies. It is obtained from man or animals that have survived exposure to an antigen.

Antitoxin—A substance found in the blood serum or other body fluids that is specifically antagonistic to a toxin (antibody developed against a toxin) and which acts to neutralize it.

Antivenin—A blood serum containing antibodies against venom, particularly snake venom.

Aphid—A small, homopterous insect which lives on plants and sucks their juices; a plant louse.

Aqueous—Watery; prepared with water.

Arachnid—One of a class of arthropods, including the ticks, mites, spiders, and scorpions.

Arthritis—Inflammation of a joint.

Arthropod—One of a class of animals with segmented body and jointed legs; examples are insects, arachnids, and crustaceans.

Aseptic—Free of living microorganisms; free of septic material.

Asexual—Having no sex; not involving sex; not sexual.

Attenuation—The process of reducing the virulence of a microorganism by cultivation on artificial media or by repeated inoculation in an animal host; or the weakening of a toxin or microorganism by chemical or heat treatment.

Autoclave—An apparatus for effecting sterilization by steam under pressure; the process of rendering sterile by subjecting to steam under pressure.

Autopsy—Post mortem examination; examination of a body after death to determine the cause of death.

Avirulent—Not virulent.

Bacillus; bacilli (pl.)—A rod-shaped bacterium.

Bacteremia—The presence of living bacteria in the blood.

Bactericide—An agent that destroys bacteria.

Bacteriology—The science which deals with bacteria.

Bacteriophage—An ultramicroscopic, viral parasite of bacteria.

Bacteriostasis—Inhibition of growth of bacteria, without destruction.

Bacterium; bacteria (pl.)—A one-celled microorganism which has no chlorophyll and reproduces by dividing in one, two, or three directions of space.

Bang's disease—Infectious abortion, or brucellosis, of cattle; undulant fever in man.

Basidiospore—A spore produced on a basidium.

Basidium—A club-shaped structure of rust fungi that produces basidiospores.

Biological agent—A microorganism which causes disease in man, plants, or animals, or causes the deterioration of materiel.

Bipolar—Having two poles; in bacteriology may refer to staining confined to the poles (end) of the cell; having flagella at each pole of the cell.

Botany—The science which deals with plants.

Botulism—Poisoning by toxin derived from the microorganism *Clostridium botulinum*.

Bronchitis—Inflammation of the bronchial tubes.

Brucellosis—An infection caused by one of the species of *Brucella* (*Br. melitensis*, *Br. abortus*, or *Br. suis*).

Bubo—Inflammatory swelling of a lymphatic gland, usually in the groin or armpit.

Callus—A hard, thickened area found around the segments of a broken bone, as differentiated from such areas on certain skin surfaces.

Capsule—A fibrous, mucoid, or membranous envelope or covering of certain organisms.

Carbohydrate—An organic substance composed of hydrogen, oxygen, and carbon such as starch, sugar, cellulose, and gums.

Carbuncle—A painful, local inflammation of the subcutaneous tissue, usually larger than a boil, which later becomes perforated and discharges pus through a number of openings.

Cardiac—Pertaining to the heart.

Carrier—An individual who harbors specific disease organisms, without showing clinical symptoms, and serves as a means of conveying infection.

Casualty—An injured, disabled, or dead individual; a military person unable to perform his duty.

Catabolism—The destructive process by which complex substances are converted by living cells into more simple compounds.

Catarrhal—Pertaining to inflammation of a mucous membrane accompanied by discharge of mucus.

Cell—A small mass of protoplasm, often including a nucleus, surrounded by a semipermeable membrane or cell wall. It is the structural and functional unit of all living organisms, plant and animal, with the possible exception of viruses.

Cereal—Pertaining to grain or the grasses which produce it.

Chemotherapy—The treatment of disease by chemicals that affect the causative organism unfavorably without causing serious reaction in the patient.

Chloromycetin—An antibiotic substance derived from cultures of *Streptomyces venezuelae*; also produced synthetically. Proprietary name for chloramphenicol.

Chlorophyll—The green coloring matter of plants, by means of which photosynthesis is accomplished.

Chronic—Long continued; opposite of acute.

Cilia—Hairlike projections or lashes, found on many cells, capable of vibratory or lashing movement. They may serve as organs of locomotion for small organisms or to produce a current of fluid, as in the upper respiratory tract of man.

Clinical—Pertaining to the observation and treatment of patients, as distinguished from laboratory or experimental investigation.

Cloven-footed—Having the foot divided or cleft in two or more parts, as in cattle and sheep; cloven-hoofed.

Coccus; cocci (pl.)—A spherical bacterium.

Coelenterates—A division of invertebrate (no backbone) animals, including corals, sea anemones, and jellyfish.

Colitis—Inflammation of the colon (a part of the large intestine extending to the rectum).

Collodion—A syrupy or viscous solution of pyroxylin (guncotton) in ether and alcohol.

Colloid—Most frequently refers to a colloidal solution, which is a dispersion in which the particles range from larger than molecular sizes to about 100 millimicrons. The behavior of such a solution is intermediate between a suspension and a true solution. Examples of colloidal systems are aqueous starch solutions, emulsions, fog, and aerosols.

Colony—A collection or group of microorganisms in a culture; they are derived from the increase of a single organism or group of organisms. On solid culture media, a colony may be visible to the naked eye.

Commensal—An organism which lives in, with, or on another organism, and which derives benefit from that organism without injuring or benefiting the organism.

Communicable—Capable of being transmitted directly from one individual to another.

Congenital—Existing at, and usually before, birth.

Contagious—Directly transmissible from one individual to another.

Contagious disease—An infectious disease capable of being directly transmitted from one individual to another. Many infectious diseases are not contagious but require some special method of transmission or inoculation.

Contaminate—To introduce an impurity; for instance, a foreign microorganism developing accidentally in a pure culture. Clothing containing microorganisms is said to be contaminated.

- Copulation*—Sexual congress; coitus.
- Cotyledon*—The first leaf or pair of leaves developing in a seed plant. These leaves contain the major food reserves of the seed.
- Covert*—Hidden, concealed, insidious.
- Crucifer*—Belonging to the family of herbs including the mustards, cabbages, turnips, radishes, and cresses.
- Crustacea*—A large class of animals, including lobsters, crabs, shrimp, and barnacles.
- Culture*—A growth of microorganisms artificially maintained.
- Culture medium*—Any preparation used for the culture of microorganisms.
- Cutaneous*—Pertaining to the skin.
- Cuticle*—The epidermis, or outer layer of the skin.
- Cyanosis*—Blueness of the skin due to insufficient oxygen in the blood.
- Debilitating*—Weakening or lessening of strength.
- Decay rate*—The predictable rate at which microorganisms die.
- Decontamination*—Removal or neutralization of contaminating material, such as pathogenic microorganisms or their toxic products.
- Dehydrate*—To remove water from.
- Deliquescent*—Having the property of taking up moisture from the air to such a degree that the absorbing substance is itself dissolved in the absorbed water.
- Dermatitis*—Inflammation of the skin.
- Desiccate*—To dry completely.
- Devitalize*—To deprive of life or vitality.
- Diplococcus*—Gram-positive (few gram-negative), round (somewhat elongated or lance-shaped) bacteria growing in pairs.
- Disease*—A deviation from the normal state or function of a cell, an organ, or an individual.
- Disinfect*—To free from pathogenic organisms, or to destroy them.
- Disinfectant*—An agent, usually chemical, that destroys infective agents.
- Dissemination*—Distribution or spreading.
- DNA*—Deoxyribonucleic acid. Found in microorganisms in the chromosomes or in the central core of viruses.
- Droplet infection*—Infection spread by droplets of contaminated respiratory or oral discharges dispersed in the air by sneezing and coughing.
- Dysentery*—A disorder marked by inflammation of the intestines, particularly the colon, accompanied by pain in the abdomen, straining, and frequent stools containing blood and mucus; dysenteries are caused by bacteria, protozoa, or parasitic worms, or by some chemical irritant.
- Emulsion*—A dispersion of two immiscible liquids, one being dispersed in the other in the form of fine droplets.
- Encapsulate*—To include within a capsule.
- Endemic*—Native to, or prevalent in, a particular district or region; an endemic disease has a low incidence but is constantly present in a given community.
- Endospore*—A resistant, dormant cell of some bacteria.
- Endotoxin*—A poisonous substance that is produced within a microorganism and retained within the cell until the cell disintegrates, upon which it is released.
- Enterotoxin*—A toxin which is specific for intestinal mucosa cells; also a toxin formed in the intestine.
- Environment*—The external surroundings and influences.

Enzootic—Occurring endemically among animals; constantly present in a given animal population, but having a low incidence.

Enzyme—A protein produced by a living organism, which catalyzes one or more chemical reactions. Enzymes are usually easily destroyed or denatured by changes in pH, temperature, and other environmental factors.

Epidemic—An outbreak of a contagious, infectious disease (i.e., one which is transmitted from an infected man to a noninfected man by direct contact, droplet inhalation, or insect vectors).

Epidemicity—Capability of rapid spread; quality of being epidemic.

Epidemiology—The study of the community aspects of disease.

Epidermis—The outermost layer of the skin.

Epiphytotic—An outbreak of disease among plants, such as certain fungal diseases. Analogous to epidemics in man and epizootics among animals.

Epizootic—An outbreak of disease among animals. Analogous to epidemics in man and epiphytotics in plants.

Equine—Pertaining to or like a horse.

Eruption—A rash, visible lesion, or injury of the skin characterized by redness or prominence, or both.

Erythrogenic—Producing or causing a rash. Producing a red appearance.

Ester—A compound formed from an alcohol and an acid by the removal of water.

Exanthema—An eruptive disease or the eruption which accompanies the disease.

Excrement—Waste material discharged from the body, especially fecal matter.

Excretion—Waste material, particularly the urine and sweat, eliminated by the body.

Exotoxin—A poisonous substance produced and excreted by a living organism.

Expectoration—The act of discharging mucus or other fluids from the lungs, trachea, or mouth by spitting.

Exudate—Any substance which becomes deposited in or on a cell or tissue following expulsion by a vital process.

Facultative—Having the power to live under different conditions; opposite of obligate; voluntary; potential. A facultative aerobe is a microorganism which is essentially an anaerobe but which can grow in the presence of free oxygen; a facultative anaerobe is a microorganism which is essentially an aerobe but which can grow in the absence of free oxygen.

Fatigue—Weariness from labor or exhausting conditions where cells or organs have undergone excess activity so that they respond to stimulation with less than normal activity.

Fauces—The passage from the mouth to the pharynx.

Febrile—Pertaining to fever; feverish.

Fever—Abnormally high body temperature; characterized by marked increase of temperature, acceleration of the pulse, increased tissue destruction, restlessness, and sometimes delirium.

Fibrin—A whitish, insoluble, fibrous protein formed from a soluble precursor protein (fibrinogen) in the clotting of the blood.

Filament—A delicate thread or fiber.

Filtrable—Capable of passing through a bacterial filter made of unglazed porcelain or compressed infusorial earth that arrests the passage of bacteria. The term "filtrable viruses" was formerly used to describe ultramicroscopic viruses.

Fission—The act of splitting; form of asexual reproduction in which the cell spontaneously divides into nearly equal parts, each of which grows into a complete organism, as observed in bacteria.

Flagellum; flagella (pl.)—Whiplike appendages used to propel a microorganism; usually longer and fewer in number than cilia.

Focus of infection—The localized region or chief site of a morbid (diseased) process.

Follicle—A very small excretory or secretory gland; for example, a hair follicle.

Fomite (fomes)—Any substance other than food which may transmit or harbor an infectious agent, such as contaminated bedding, clothing, and dishes.

Formalin—A 40-percent solution of gaseous formaldehyde in water.

Fumigation—Exposure to chemical fumes which destroy living organisms.

Fungicide—A substance that destroys fungi or inhibits the germination of fungal spores.

Fungus—Any one of a group of thallophytic plants, including the molds, mildews, rusts, smuts, and mushrooms; it does not contain chlorophyll, and reproduction is mainly by sporulation.

Gall—In plants a swelling caused by attacks of parasites, such as the gallfly and certain aphids or by bacteria; also the bile produced by the liver.

Gastroenteritis—Inflammation of the stomach and intestines.

Genera—A taxonomic category subordinate to a tribe and superior to a species.

Germinate—To sprout; to begin to grow or develop.

Glycoside—One of a class of chemical compounds consisting of a sugar molecule combined with one or more substances, many of which are poisons.

Gram's stain—A differential stain used in the primary step of microorganism identification. The ability or inability of the microorganism to retain the stain determines whether the microorganism is gram-positive or gram-negative.

Granuloma—A tumor or other abnormal growth made up of granulation tissue (small, round, fleshy masses).

Heme—The oxygen-carrying red pigment of the red blood corpuscles; the nonprotein portion of hemoglobin.

Hemolysis—The destruction of red blood corpuscles with consequent liberation of the hemoglobin they contain.

Hemorrhage—Bleeding.

Hepatitis—Inflammation of the liver.

Herbivorous—Subsisting on plants, grasses, or herbs.

Hermaphroditic—Having both male and female reproductive organs.

Heterogeneous—Composed of dissimilar elements or ingredients.

Homogeneous—Composed of similar elements or ingredients; of uniform quality throughout.

Hormone—A specific chemical substance that is secreted into the body fluids by a secretory gland and that produces effects on the activities of other organs. Examples are adrenalin and pituitrin.

Host—Any animal or plant which harbors or nourishes another organism.

Hydrolyze—To subject to hydrolysis; to split a chemical bond with water.

Hygiene—The science of health and the preservation of good health.

Hypha; hyphae (pl.)—Threadlike portions of individual filaments of a fungus.

Immune—Resistant to any particular infectious disease.

Immunity—The state or power of resisting the development of an infectious disease.

Immunize—To render resistant to any particular disease.

Inanimate—Without life.

Incapacitation—Disablement.

Incidence rate—The range or rate of new occurrences, as of a disease.

Incubation period—The time interval between the introduction into the body of an infectious agent and the appearance of the first symptoms of disease.

Infection—The invasion of body tissues by microorganisms, with their subsequent growth and reproduction; usually spoken of in relation to the disease or injury that is caused.

Infectious disease—A disease which is caused by a living agent, such as bacteria, rickettsiae, viruses, or fungi; may or may not be contagious.

Infective dose—The number of microorganisms required to produce an infection.

Infectivity—The quality of being infectious or the capacity of an organism to invade and establish itself as a parasite in the tissues of a host.

Infestation—Invasion of the body by arthropods or macroparasites, including insects, mites, ticks, or intestinal parasites (worms).

Inflammation—Reaction of tissues to injury; characterized by pain, heat, redness, or swelling of the affected parts.

Ingestion—Act of taking material into the body by mouth.

Inoculate—To introduce a microorganism, vaccine, immunizing serum, or other antigenic substance for preventive, curative, or experimental purposes; to place a suspected or known microorganism in or on any culture medium.

Inoculum—The substance used in an inoculation.

Inorganic—Generally pertaining to chemical compounds not composed primarily of carbon, but including cyanide and carbonates.

Insect—A member of a class of small invertebrate animals, with three clearly defined body regions—the head, thorax, and abdomen—with only three pairs of legs, and usually with wings. Examples are beetles, bugs, bees, and flies.

Insecticide—An agent or material that kills insects.

Intracellular—Inside, or within, the cell.

Invasiveness—The ability of a microorganism to spread throughout the tissues once it has entered the body.

Jaundice—A disease symptom characterized by yellowing of the skin and eyes and by a deep yellow color of the urine; this yellowing is due to the presence of bile pigments in the blood and tissue, usually brought about by liver damage. Also known as icterus.

Lacerate—To tear.

Larva; larvae (pl.)—The immature, wingless, and often wormlike form in which certain invertebrates hatch from the egg and in which form they remain until the adult or preadult stage.

Latent period—A period of seeming inactivity.

Lesion—Injury, mechanical or pathological; morbid change.

Lethal—Deadly; fatal.

Leucocidin—A substance (enzyme) secreted by some pathogenic bacteria which destroys white blood cells (leukocytes).

Leukocyte—A white blood cell; an amoeboid cell which is found in the blood, lymph, and body tissues and which forms the chief cellular element in pus.

Lumbar—Pertaining to the loins (a lumbar vertebra or nerve); lower region of the back.

Lymph—A transparent fluid found in the lymphatic vessels. It is essentially blood without red corpuscles.

Lymph gland—One of the masses of lymphoid tissue from which the lymphocytes (specific variety of leukocyte) are derived; also serves to clarify the lymph as it flows through the lymph channels.

Lymphatic system—The system of vessels which drains the lymph from various body tissues and returns it to the bloodstream.

Lyophilization—The process of drying substances, including microorganisms, in the frozen state under a vacuum; sometimes referred to as freeze drying.

Macerate—To soften by soaking, causing disorganization of tissue cells.

Macrophage—A large, mononuclear leukocyte; fixed or wandering phagocytic cell which originates in the tissues.

Malaise—A feeling of bodily discomfort.

Malignant—Tending to go from bad to worse; capable of spreading from one site within the tissues to another.

Malnutrition—Any disorder of nutrition, usually referring to a lack of nutrient material or an inability to utilize a nutrient.

Medium; media (pl.)—Refers to a culture medium; a variety of materials and their combinations used for growing microorganisms. It may be solid or liquid.

Membrane—A thin layer of tissue that covers a surface or divides a space or organ.

Meningitis—Inflammation of the meninges or certain membranes that envelop the brain and spinal cord.

Metabolism—The sum total of the chemical and physical changes constantly taking place in living matter. Component processes of metabolism of biological substances, including microorganisms, are the degradation of food stuffs, the synthesis of cellular constituents, and the transfer of energy. All are dependent on the catalytic actions of enzymes.

Microbiology—The science which deals with the study of microorganisms.

Micron—One-thousandth (0.001) part of a millimeter or one-millionth (0.000001) part of a meter. It is equivalent to about one twenty-five-thousandth (0.00004) of an inch.

Microorganism—A minute, living organism too small to be seen with the unaided eye.

Mite—Minute animals of the order *Acarina* (except ticks) related to spiders; parasitic on man and animals, producing various irritations of the skin. Chiggers are an example.

Molds—Minute saprophytic or parasitic filamentous fungi which produce a woolly or cottony growth on various forms of organic matter.

Molecule—A chemical combination of two or more atoms which form a specific chemical substance.

Morbidity—The state of being diseased. May be expressed as the rate or ratio of sick persons to the total population.

Morphology—The science of the form and structure of organized beings.

Mortality rate—The ratio of the number of deaths from a given disease to the total number of cases of that disease.

Motile—Capable of spontaneous movement.

Motor nerve—A nerve that transmits an impulse from the central nervous system or ganglion to a muscle, causing movement.

Mucosa—The mucous membrane; a membrane, secreting mucus, which lines passages and cavities communicating with the exterior (gastrointestinal, respiratory, and genitourinary tracts).

Mucous—Pertaining to or resembling mucus; also used to describe a gland or tissue capable of secreting mucus.

Mucus—The viscid (sticky) secretion of the mucous glands.

Mycelium—The vegetative body of a fungus composed of a mass of filaments called hyphae.

Nausea—Tendency to vomit; sickness of the stomach.

Necrosis—Death of a cell or group of cells.

Neoplastic—Pertaining to or like an abnormal growth.

Nephritis—Inflammation of the kidney.

Neuritis—Inflammation of a nerve, accompanied by pain and tenderness over the nerve.

Neurotoxic—Poisonous to nerve tissue.

Neurotoxin—Toxin which attacks any nerve tissue.

Neurotropic—Having an affinity for nerve tissue.

Neutralize—To render neutral.

Node—A swelling or protuberance; or a specific structure, as a lymph node.

Nodular—Like a nodule or node; marked with nodules.

Nodule—A small node or lump that is solid and can be detected by touch.

Nucleus—A body within a cell that is the center of reproductive activities of the cell; distinguished from the rest of the cell by its dense structure; contains the chromatin body.

Nutrition—The elements of nourishment obtained through the process of assimilating (absorbing) food.

Nymph—A stage in the life cycle of certain arthropods, as the ticks, between the larval and adult forms. A nymph resembles the adult in appearance.

Obligate—Limited to a single life condition, as obligate anaerobe or obligate parasite; opposite of facultative.

Optimum—That condition of surroundings which is conducive to the most favorable activity or function.

Organic—Pertaining to or derived from living organisms; in chemistry, pertaining to the carbon compounds.

Organism—Any organized living being, animal or plant.

Osmosis—The process of diffusion of a solvent through a semipermeable membrane from a less concentrated to a more concentrated solution, which tends to equalize the concentrations of the two solutions.

Overt—Open; manifest.

Pandemic—A disease situation occurring over a great area (a continent or more) for a protracted period of time.

Parasite—A plant or animal living on or within another living organism or host at whose expense it is maintained.

Passive immunity—Immunity acquired by introduction of antibodies produced in the body of another individual or animal.

Pasteurization—The partial sterilization of a food by heating to a moderate temperature (143° to 161° F.) for a definite time, resulting in destruction of certain pathogens and other undesirable microorganisms.

Pathogen—A disease-producing microorganism.

Pathogenic—Giving origin to disease.

Pathogenicity—The ability of a microorganism to produce disease; virulence.

Pathology—The science dealing with the structural and functional changes which result in or from disease.

Penicillin—An antibiotic compound obtained from cultures of the *Penicillium notatum*-*Penicillium chrysogenum* group of molds, which is bacteriostatic for numerous bacteria and other microorganisms.

Peristalsis—Waves of contractive movements by which the alimentary canal propels its contents.

Peritonitis—Inflammation of the peritoneum, a membrane lining the abdominal walls and covering the viscera.

Permeable—Penetrable; refers to membranes that allow the passage of fluids.

pH—Symbol used to express hydrogen ion concentration. Negative log of the hydrogen ion concentration.

Phagocyte—Any cell that is active in ingesting and destroying foreign protein or microorganisms in the blood or tissues.

Pharmaceutical—Of or pertaining to pharmacy or to drugs.

Phenol—Carbolic acid (C_6H_5OH); a colorless, crystalline, poisonous chemical compound obtained by the distillation of coal tar. In solution it is used as an antiseptic, a disinfectant, and a germicide.

Photosynthesis—The process in which plants use the energy of the sun to transform carbon dioxide and water into carbohydrates. This process requires the presence of chlorophyll.

Phylum; phyla (pl.)—One of the primary or main divisions of the animal or plant kingdom.

Physiology—The study of the functions of the living organism and its parts.

Phytotoxin—A toxin derived from a plant; ricin from the castor bean is an example.

Placenta—The organ within the uterus which establishes communication between the mother and the fetus by means of the umbilical cord.

Plasma—The fluid portion of the blood in which the corpuscles are suspended.

Pollen—The mass of microspores (male fertilizing elements) of flowering plants.

Polyvalent vaccine—A vaccine made up of a number of strains of the same organism or of different organisms.

Post mortem—Occurring or performed after death.

Prognosis—A forecast of the course of a disease; also the outlook for recovery as indicated by the nature and symptoms of the case.

Propagate—To cause to continue or multiply by generation; to reproduce; to cause to spread or extend.

Prophylaxis—Prevention of disease, or preventive treatment.

Prostration—Extreme exhaustion.

Protein—Any one of a group of complex, organic, nitrogenous compounds existing in all plants and animals, which form the principal active constituents of the cell protoplasm.

Protoplasm—The only known form of matter in which life is manifested; the essential substance of the cell. It is usually a thick, viscous, semifluid or almost jellylike, colorless, translucent material containing a large proportion of water and holding fine granules in suspension.

Protozoan; protozoa (pl.)—One of the lowest divisions of the animal kingdom, including one-celled organisms.

Pseudopodia—(Greek, false foot) Temporary protrusions of the protoplasm of a cell, enabling it to move about or take up food (amoeboid movement).

Pulmonary—Pertaining to the lungs.

Pupa; pupae (pl.)—An intermediate, usually quiescent, form assumed by many insects after the larval stage and maintained until the beginning of the adult stage.

Pupate—To become a pupa.

Pus—A liquid inflammation product, made up of dead and living white blood cells, digested bacteria, tissue debris, lymph, fibrin, and serum.

Pustule—A small elevation of the skin filled with pus.

Quarantine—Isolation of infected individuals and of possible carriers and contacts for a period of time to prevent disease transmission.

Resistance—The natural ability of a person to ward off deleterious effects of pathogenic microorganisms.

Respiration—The act or function of breathing.

Respiratory—Pertaining to respiration.

Rickettsia; rickettsiae (pl.)—Gram-negative, nonmotile, intracellular, parasitic microorganisms, intermediate in size between the bacteria and viruses.

RNA—Ribonucleic acid. In microorganisms it is responsible for directing metabolic functions within the cell. Central core in many viruses.

Rodent—Gnawing animal, such as a rat, mouse, squirrel, beaver, or rabbit.

Saliva—A clear, alkaline, somewhat viscid digestive fluid secreted by the salivary glands of the mouth.

Salivation—A discharge of saliva.

Sanitation—The establishment of environmental conditions favorable to health.

Saprophyte—A microorganism which lives upon dead or decaying organic matter.

Semipermeable—Permitting the passage of certain molecules and holding back others.

Sensory—Pertaining to sensation; sensory nerves convey impulses from the sense organs to the central nervous system.

Septic—Produced by or due to putrefaction or the presence of microorganisms.

Septicemia—A morbid condition characterized by the presence of pathogenic microorganisms and their associated poisons in the blood; invasion and reproduction of microorganisms in the bloodstream; blood poisoning.

Serological—Pertaining to blood sera and the study of sera.

Serum; sera (pl.)—The clear liquid which separates in the clotting of blood from the clot and the corpuscles; differs from plasma in that it does not contain fibrin.

Sexual—Pertaining to sex.

Sheath—Botanically, the base of a leaf when covering a stem or branch, as in grasses.

Sinus—A cavity or hollow space; an air cavity in a cranial bone, especially one connected with the nasal passages.

Slurry—Wet form of biological agent; a thin, watery mixture.

Species—A primary subdivision of a genus; a group of animals or plants which possess, in common, one or more distinctive characters and do or may interbreed and reproduce their characters in their offspring.

Spirillum; spirilla (pl.)—A long, rigid, curved (comma-shaped or spiral), flagellate bacterium.

Spirochete—Any long, spiral, cylindrical, flexible microorganism which is nonsporulating and motile, including those causing syphilis and relapsing fever.

Sporadic—Occurring only occasionally; not at regular intervals.

Spores—Primitive reproductive bodies of fungi; resistant, dormant cells of some bacteria.

Sporulation—The formation of spores.

Stability—The ability of an organism to resist harmful physical and chemical changes in its environment.

Staphylococcus—Any of a genus of gram-positive bacteria (cocci) which often form grapelike clusters.

Sterilization—The process of killing all living cells, especially microorganisms, by heat, chemicals, or other means.

Stomatitis—Inflammation of the mouth, usually attended by pain and salivation and often by unpleasant odor of the breath.

Strain—A group of organisms within a species or variety, characterized by some particular quality.

Streptococcus—Any of a genus of spherical, nonmotile, gram-positive bacteria occurring in pairs or chains and dividing in one plane only.

Streptomycin—An antibiotic obtained from cultures of *Streptomyces griseus* and active against a variety of gram-negative bacteria.

Stupor—Partial or nearly complete unconsciousness.

Subclinical—Prior to the appearance of symptoms of a disease; without clinical manifestations.

Sulfonamide—The chemical group SO_2NH_2 . Some compounds containing this group exert a powerful bacteriostatic action.

Susceptibility—State of being readily affected or acted upon.

Symptoms—Functional evidence of disease; a change in condition indicative of some mental or bodily state.

Synthesize—To build up a chemical compound from its elements or other compounds.

Streptokinase—An enzyme produced by some pathogenic bacteria to break down localized fibrin accumulations so that the pathogens may spread in the body.

Teliospore—A thick-walled spore (that produces a basidium) developed in the final stage in the life cycle of rust fungi.

Terramycin—A crystalline antibiotic isolated from a soil fungus, *Streptomyces rimosus*; of low toxicity and effective against a wide variety of microorganisms.

Tetanus—An acute infectious disease caused by a toxin produced in the body by the bacillus *Clostridium tetani*; continuous spasm of a muscle.

Thallophyte—A simple plant, not differentiated into roots, stems, and leaves; a member of the division of the plant kingdom which includes algae, fungi, lichens, and bacteria. Some authorities place bacteria in a separate group, the *Protophytes*.

Therapeutic—Pertaining to the science and art of healing; having value as a treatment.

Therapy—The treatment of disease; therapeutics.

Thermophilic—Growing best at elevated temperatures; said of bacteria which develop best at a temperature of 104° F. (40° C.) to 158° F. (70° C.). Examples are some of the bacteria found in milk, fermenting manure, or hot springs.

Thorax—The chest; the portion of the body between the head (in insects) or neck (in vertebrates) and the abdomen.

Tissue—A group of specialized cells united in the performance of a particular function.

Toxemia—A general poisoning or intoxication due to absorption of products (toxins) of microorganisms formed at a local source of infection.

Toxic—Poisonous; pertaining to, due to, or of the nature of, a poison.

Toxicity—The quality of being poisonous.

Toxin—Generally, any poisonous substance of microorganism, vegetable, or animal origin. True toxins are of a proteinlike nature, more or less unstable, require a period of incubation or a latent period to produce symptoms, and induce in suitable animals the formation of specific antitoxins.

Toxoid—A chemically altered toxin, changed so that it is no longer poisonous, but which is still antigenic and produces active immunity when injected into an animal or man.

Translucent—Partly transparent; admitting passage of light but diffusing it so that objects beyond cannot be clearly distinguished through the substance.

Trypanosome—Any of a genus of parasitic flagellate protozoa infesting the blood of various animals, including man, and usually transferred by the bite of an insect.

Udder—The mammary or milk glands of cows and certain other animals.

Ulcer—An interruption (loss of substance) on the skin or mucous surface which causes a gradual disintegration and necrosis of tissues. Thus, when a wound has the presence of a granulating base, it may be an ulcer.

Ultraviolet—Light waves shorter than the visible blue violet waves, but longer than X-rays. Ultraviolet radiation is very effective in killing microorganisms.

Unicellular—Made up of a single cell.

Uredospore—In the rust fungi, a thin-walled summer spore that develops a mycelium (the network of rootlike, threadlike filaments that constitute the bodies of fungi).

Vaccination—General meaning: protective inoculation with microorganisms, killed or attenuated. Specific meaning: protective inoculation against smallpox by inoculation with vaccinia (cowpox) virus.

Vaccine—A preparation of killed or attenuated infective or toxic agent used as an inoculation to produce active artificial immunity.

Vascular—Pertaining to blood vessels, or the presence of such vessels.

Vector—A carrier; especially the animal or intermediate host that carries a pathogen from one host to another, as the malaria-carrying mosquito.

Vegetative cells—Nonspore-forming bacteria or spore-forming bacteria in their nonsporing state.

Vesicle—A small sac or cavity containing fluid; or a small blister.

Veterinary—Pertaining to the science and art dealing with the prevention, cure, or alleviation of disease in animals.

Viable—Living.

Vibrio—A small, curved, rod-shaped bacterium motile by means of one or more polar flagella.

Viremia—Presence of living virus in the blood.

Virulence—The degree of pathogenicity of a microorganism as indicated by case fatality rates and/or its ability to invade the tissues of a host.

Virulent—Exceedingly infectious; characterized by virulence.

Virus; viruses (pl.)—Infectious agent, smaller than bacteria and rickettsiae, capable of living and replicating only within a living susceptible host cell; cannot survive or be grown on artificial media.

Viscus; viscera (pl.)—Large internal organs in any one of the great cavities of the body, especially in the abdomen or thorax.

Vitamin—Any of many organic substances that are necessary for the normal metabolic functioning of the body.

Vomit—Matter which is vomited.

Zoology—The branch of biology dealing with animals.

Zoonosis; zoonoses (pl.)—A disease of animals that may be transmitted to man.

Zootoxin—A toxin or poison of animal origin such as the venom of snakes, spiders, and scorpions.

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